Model: model

June 10, 2021

Contents

1 Stage Total

1.1 Total

This process summarizes the contribution of the individual Modules to the total NH3 emission from a farm.

Outputs

nh3_nanimalproduction Annual NH3 emission from farm.

```
Val(nh3_napplication, Application) P+
Val(nh3_nstorage, Storage) P+
Val(nh3_nlivestock, Livestock);
```

nh3_ntotal Annual NH3 emission from farm.

```
Out(nh3_nanimalproduction) +
Val(nh3_nplantproduction, PlantProduction)
```

n_remain_animalproduction Annual total N remaining in soil.

```
Val(n_remain_application, Application) P+
Val(n_remain_grazing, Livestock);
```

tan_remain_animalproduction Annual total TAN remaining in soil.

```
Val(tan_remain_application, Application) P+
Val(tan_remain_grazing, Livestock);
```

2 Stage Livestock

2.1 Livestock

This process summarizes the annual NH3 emission from livestock (housing, yard and grazing) for all animal categories. Further it calculates the N flux into storage from housing and yard. The manure is splited in solid and liquid/slurry.

Outputs

n_excretion Total annual N excreted by all animals.

```
Sum(n_excretion, Livestock::OtherCattle::Excretion) P+
Sum(n_excretion, Livestock::DairyCow::Excretion) P+
Sum(n_excretion, Livestock::Pig::Excretion) P+
Sum(n_excretion, Livestock::FatteningPigs::Excretion) P+
Sum(n_excretion, Livestock::Equides::Excretion) P+
Sum(n_excretion, Livestock::SmallRuminants::Excretion) P+
Sum(n_excretion, Livestock::RoughageConsuming::Excretion) P+
Sum(n_excretion, Livestock::Poultry::Excretion);
```

n_into_housing Total annual N excreted by all animals.

```
Sum(n_into_housing, Livestock::OtherCattle::Housing) P+
Sum(n_into_housing, Livestock::DairyCow::Housing) P+
Sum(n_into_housing, Livestock::Pig::Housing) P+
Sum(n_into_housing, Livestock::FatteningPigs::Housing) P+
Sum(n_into_housing, Livestock::Equides::Housing) P+
Sum(n_into_housing, Livestock::SmallRuminants::Housing) P+
Sum(n_into_housing, Livestock::RoughageConsuming::Housing) P+
Sum(n_into_housing, Livestock::Poultry::Housing);
```

n_into_yard Total annual N excreted by all animals.

```
Sum(n_into_yard, Livestock::OtherCattle::Yard) P+
Sum(n_into_yard, Livestock::DairyCow::Yard) P+
Sum(n_into_yard, Livestock::Equides::Yard);
```

n_into_housing_and_yard Total annual N excreted by all animals.

```
Out(n_into_housing) P+
Out(n_into_yard);
```

n_into_grazing Total annual N excreted by all animals.

```
Sum(n_into_grazing, Livestock::OtherCattle::Grazing) P+
Sum(n_into_grazing, Livestock::DairyCow::Grazing) P+
Sum(n_into_grazing, Livestock::Pig::Grazing) P+
Sum(n_into_grazing, Livestock::FatteningPigs::Grazing) P+
Sum(n_into_grazing, Livestock::Equides::Grazing) P+
Sum(n_into_grazing, Livestock::SmallRuminants::Grazing) P+
Sum(n_into_grazing, Livestock::RoughageConsuming::Grazing) P+
Sum(n_into_grazing, Livestock::Poultry::Grazing);
```

tan_excretion Total annual N excreted by all animals.

```
Sum(tan_excretion, Livestock::OtherCattle::Excretion) P+
Sum(tan_excretion, Livestock::DairyCow::Excretion) P+
Sum(tan_excretion, Livestock::Pig::Excretion) P+
Sum(tan_excretion, Livestock::FatteningPigs::Excretion) P+
Sum(tan_excretion, Livestock::Equides::Excretion) P+
Sum(tan_excretion, Livestock::SmallRuminants::Excretion) P+
Sum(tan_excretion, Livestock::RoughageConsuming::Excretion) P+
Sum(tan_excretion, Livestock::Poultry::Excretion);
```

tan_into_housing Total annual N excreted by all animals.

```
Sum(tan_into_housing, Livestock::OtherCattle::Housing) P+
Sum(tan_into_housing, Livestock::DairyCow::Housing) P+
```

```
Sum(tan_into_housing, Livestock::Pig::Housing) P+
Sum(tan_into_housing, Livestock::FatteningPigs::Housing) P+
Sum(tan_into_housing, Livestock::Equides::Housing) P+
Sum(tan_into_housing, Livestock::SmallRuminants::Housing) P+
Sum(tan_into_housing, Livestock::RoughageConsuming::Housing) P+
Sum(tan_into_housing, Livestock::Poultry::Housing);
```

tan_into_yard Total annual N excreted by all animals.

```
Sum(tan_into_yard, Livestock::OtherCattle::Yard) P+
Sum(tan_into_yard, Livestock::DairyCow::Yard) P+
Sum(tan_into_yard, Livestock::Equides::Yard);
```

tan_into_housing_and_yard Total annual TAN excreted by all animals.

```
Out(tan_into_housing) P+
Out(tan_into_yard);
```

tan_into_grazing Total annual N excreted by all animals.

```
Sum(tan_into_grazing, Livestock::OtherCattle::Grazing) P+
Sum(tan_into_grazing, Livestock::DairyCow::Grazing) P+
Sum(tan_into_grazing, Livestock::Pig::Grazing) P+
Sum(tan_into_grazing, Livestock::FatteningPigs::Grazing) P+
Sum(tan_into_grazing, Livestock::Equides::Grazing) P+
Sum(tan_into_grazing, Livestock::SmallRuminants::Grazing) P+
Sum(tan_into_grazing, Livestock::RoughageConsuming::Grazing) P+
Sum(tan_into_grazing, Livestock::Poultry::Grazing);
```

has_cattle Animal categories belonging to mastercategory _cattle_ (dairy cows and other cattle). Hash entry of 1, if N flux into livestock > 0. Hash entry of 0, if N flux into livestock = 0.

```
sign(
  Sum(n_excretion, Livestock::OtherCattle::Excretion) P+
  Sum(n_excretion, Livestock::DairyCow::Excretion)
);
```

has_pigs Animal categories belonging to mastercategory _pigs_ (fattening pigs and other pigs). Hash entry of 1, if N flux into livestock > 0. Hash entry of 0, if N flux into livestock = 0.

```
sign(
  Sum(n_excretion, Livestock::Pig::Excretion) P+
  Sum(n_excretion, Livestock::FatteningPigs::Excretion)
);
```

has_others Animal categories belonging to mastercategory _others_ (equides, small ruminants and roughage consuming). Hash entry of 1, if N flux into livestock > 0. Hash entry of 0, if N flux into livestock = 0.

```
sign(
  Sum(n_excretion, Livestock::Equides::Excretion) P+
  Sum(n_excretion, Livestock::SmallRuminants::Excretion) P+
  Sum(n_excretion, Livestock::RoughageConsuming::Excretion)
);
```

has_poultry_LGO Animal categories belonging to mastercategory *poultry_LGO* (layers, growers and other poultry). Hash entry of 1, if N flux into livestock > 0. Hash entry of 0, if N flux into livestock = 0.

```
sign( Sum(n_excretion_layers_growers_other_poultry,Livestock::Poultry::Excretion) );
```

has_poultry_TB Animal categories belonging to mastercategory *poultry_TB* (turkeys and broilers). Hash entry of 1, if N flux into livestock > 0. Hash entry of 0, if N flux into livestock = 0.

```
sign(
  Sum(n_excretion_turkeys_broilers,Livestock::Poultry::Excretion)
);
```

has_no_poultry Animal categories belonging to mastercategory *no_poultry* (all except poultry). Hash entry of 1, if N flux into livestock > 0. Hash entry of 0, if N flux into livestock = 0.

```
Out(has_pigs) P+
Out(has_cattle) P+
Out(has_others);
```

has_poultry Animal categories belonging to mastercategory _poultry_ (all poultry). Hash entry of 1, if N flux into livestock > 0. Hash entry of 0, if N flux into livestock = 0.

```
Out(has_poultry_LGO) P+
Out(has_poultry_TB);
```

n_out_housing_liquid Annual N flux (liquid share) out of housing.

```
Sum(n_outhousing_liquid, Livestock::Pig::Housing) P+
Sum(n_outhousing_liquid, Livestock::FatteningPigs::Housing) P+
Sum(n_outhousing_liquid, Livestock::OtherCattle::Housing) P+
Sum(n_outhousing_liquid, Livestock::DairyCow::Housing);
```

n_out_housing_solid Annual N flux (liquid share) out of housing.

```
Sum(n_outhousing_solid, Livestock::Pig::Housing) P+
Sum(n_outhousing_solid, Livestock::FatteningPigs::Housing) P+
Sum(n_outhousing_solid, Livestock::OtherCattle::Housing) P+
Sum(n_outhousing_solid, Livestock::DairyCow::Housing) P+
Sum(n_outhousing_solid, Livestock::Equides::Housing) P+
Sum(n_outhousing_solid, Livestock::SmallRuminants::Housing) P+
Sum(n_outhousing_solid, Livestock::RoughageConsuming::Housing) P+
Sum(n_outhousing_solid, Livestock::Poultry::Housing);
```

n_out_yard_liquid Annual N flux (liquid share) out of yard.

```
Sum(n_outyard_liquid, Livestock::OtherCattle::Yard) P+
Sum(n_outyard_liquid, Livestock::DairyCow::Yard);
```

n_out_yard_solid Annual N flux (liquid share) out of yard.

```
Sum(n_outyard_solid, Livestock::Equides::Yard);
```

n_out_livestock_liquid Annual N flux (liquid share) from housing and yard into the storage from all animal besides poultry.

```
Out(n_out_housing_liquid) P+
Out(n_out_yard_liquid);
```

n_out_livestock_liquid_pigs_share Scalar. Share of annual liquid N flux from housing and yard into the storage from pigs (scaled by total flux).

```
return 0 unless scalar(Out(n_out_livestock_liquid)) > 0;
(
  scalar(Sum(n_outhousing_liquid,Livestock::Pig::Housing)) +
  scalar(Sum(n_outhousing_liquid, Livestock::FatteningPigs::Housing))
) /
scalar(Out(n_out_livestock_liquid));
```

n_out_livestock_solid Annual N flux (solid share) from housing and yard into the storage from all animals besides poultry.

```
Out(n_out_housing_solid) P+
Out(n_out_yard_solid);
```

n_out_livestock Annual N flux (liquid and solid share) from housing and yard into the storage from all animals.

```
Out(n_out_livestock_liquid) P+
Out(n_out_livestock_solid);
```

tan_out_housing_liquid Annual N flux (liquid share) out of housing.

```
Sum(tan_outhousing_liquid, Livestock::Pig::Housing) P+
Sum(tan_outhousing_liquid, Livestock::FatteningPigs::Housing) P+
Sum(tan_outhousing_liquid, Livestock::OtherCattle::Housing) P+
Sum(tan_outhousing_liquid, Livestock::DairyCow::Housing);
```

tan_out_housing_solid Annual N flux (solid share) as TAN from housing and yard into the storage from all animals besides poultry.

```
Sum(tan_outhousing_solid, Livestock::OtherCattle::Housing) P+
Sum(tan_outhousing_solid, Livestock::DairyCow::Housing) P+
Sum(tan_outhousing_solid, Livestock::Pig::Housing) P+
Sum(tan_outhousing_solid, Livestock::FatteningPigs::Housing) P+
Sum(tan_outhousing_solid, Livestock::Equides::Housing) P+
Sum(tan_outhousing_solid, Livestock::SmallRuminants::Housing) P+
Sum(tan_outhousing_solid, Livestock::RoughageConsuming::Housing) P+
Sum(tan_outhousing_solid, Livestock::Poultry::Housing);
```

tan_out_yard_liquid Annual N flux (liquid share) out of yard.

```
Sum(tan_outyard_liquid, Livestock::OtherCattle::Yard) P+
Sum(tan_outyard_liquid, Livestock::DairyCow::Yard);
```

tan_out_yard_solid Annual N flux (solid share) as TAN from yard and yard into the storage from all animals besides poultry.

```
Sum(tan_outyard_solid, Livestock::Equides::Yard);
```

tan_out_livestock_liquid Annual N flux (liquid share) as TAN from housing and yard into the storage from all animals besides poultry.

```
Out(tan_out_housing_liquid) P+
Out(tan_out_yard_liquid);
```

tan_out_livestock_liquid_pigs_share Scalar. Share of annual liquid N flux as TAN from housing and yard into the storage from pigs (scaled by total flux).

```
return 0 unless scalar(Out(tan_out_livestock_liquid)) > 0;
(
  scalar(Sum(tan_outhousing_liquid, Livestock::Pig::Housing)) +
  scalar(Sum(tan_outhousing_liquid, Livestock::FatteningPigs::Housing))
) /
scalar(Out(tan_out_livestock_liquid));
```

tan_out_livestock_solid Annual N flux (solid share) as TAN from housing and yard into the storage from all animals besides poultry.

```
Out(tan_out_housing_solid) P+
Out(tan_out_yard_solid);
```

tan_out_livestock Annual TAN flux as TAN from housing and yard into the storage from all animals besides poultry.

```
Out(tan_out_livestock_liquid) P+
Out(tan_out_livestock_solid);
```

nh3_ngrazing Annual NH3 emission from all grazing areas and Poultry grazing activities.

```
Sum(nh3_ngrazing,Livestock::OtherCattle::Grazing) P+
Sum(nh3_ngrazing,Livestock::DairyCow::Grazing) P+
Sum(nh3_ngrazing,Livestock::Pig::Grazing) P+
Sum(nh3_ngrazing,Livestock::FatteningPigs::Grazing) P+
Sum(nh3_ngrazing,Livestock::Equides::Grazing) P+
Sum(nh3_ngrazing,Livestock::SmallRuminants::Grazing) P+
Sum(nh3_ngrazing,Livestock::RoughageConsuming::Grazing) P+
Sum(nh3_ngrazing,Livestock::Poultry::Grazing);
```

nh3_nhousing Annual NH3 emission from all housings.

```
Sum(nh3_nhousing,Livestock::OtherCattle::Housing) P+
Sum(nh3_nhousing,Livestock::DairyCow::Housing) P+
Sum(nh3_nhousing,Livestock::SmallRuminants::Housing) P+
```

```
Sum(nh3_nhousing,Livestock::RoughageConsuming::Housing) P+
Sum(nh3_nhousing,Livestock::Pig::Housing) P+
Sum(nh3_nhousing,Livestock::FatteningPigs::Housing) P+
Sum(nh3_nhousing,Livestock::Equides::Housing) P+
Sum(nh3_nhousing,Livestock::Poultry::Housing);
```

nh3_nyard Annual NH3 emission from all yards.

```
Sum(nh3_nyard,Livestock::OtherCattle::Yard) P+
Sum(nh3_nyard,Livestock::Equides::Yard) P+
Sum(nh3_nyard,Livestock::DairyCow::Yard);
```

nh3_nhousing_and_yard Annual NH3 emission from all housings and yards.

```
Out(nh3_nhousing) P+
Out(nh3_nyard);
```

nh3_nlivestock Annual NH3 emission from livestock from all animals.

```
Out(nh3_nhousing_and_yard) P+
Out(nh3_ngrazing);
```

n2_nsolid_housing_and_storage Annual N2 emission from solid manure from housing, yard and storage.

```
Sum(n2_nsolid, Livestock::OtherCattle::NxOx) P+
Sum(n2_nsolid, Livestock::DairyCow::NxOx) P+
Sum(n2_nsolid, Livestock::SmallRuminants::NxOx) P+
Sum(n2_nsolid, Livestock::RoughageConsuming::NxOx) P+
Sum(n2_nsolid, Livestock::Pig::NxOx) P+
Sum(n2_nsolid, Livestock::FatteningPigs::NxOx) P+
Sum(n2_nsolid, Livestock::Equides::NxOx) P+
Sum(n2_npoultry, Livestock::Poultry::NxOx);
```

n2_nliquid_housing_and_storage Annual N2 emission from liquid manure from housing, yard and storage.

```
Sum(n2_nliquid, Livestock::OtherCattle::NxOx) P+
Sum(n2_nliquid, Livestock::DairyCow::NxOx) P+
Sum(n2_nliquid, Livestock::Pig::NxOx) P+
Sum(n2_nliquid, Livestock::FatteningPigs::NxOx);
```

n2_nhousing_and_storage Annual N2 emission from housing, yard and storage.

```
Out(n2_nliquid_housing_and_storage) P+
Out(n2_nsolid_housing_and_storage);
```

no_nsolid_housing_and_storage Annual NO emission from solid manure from housing, yard and storage.

```
Sum(no_nsolid, Livestock::OtherCattle::NxOx) P+
Sum(no_nsolid, Livestock::DairyCow::NxOx) P+
Sum(no_nsolid, Livestock::SmallRuminants::NxOx) P+
Sum(no_nsolid, Livestock::RoughageConsuming::NxOx) P+
Sum(no_nsolid, Livestock::Pig::NxOx) P+
Sum(no_nsolid, Livestock::FatteningPigs::NxOx) P+
Sum(no_nsolid, Livestock::Equides::NxOx) P+
Sum(no_npoultry, Livestock::Poultry::NxOx);
```

no_nliquid_housing_and_storage Annual NO emission from liquid manure from housing, yard and storage.

```
Sum(no_nliquid, Livestock::OtherCattle::NxOx) P+
Sum(no_nliquid, Livestock::DairyCow::NxOx) P+
Sum(no_nliquid, Livestock::Pig::NxOx) P+
Sum(no_nliquid, Livestock::FatteningPigs::NxOx);
```

no_nhousing_and_storage Annual NO emission from housing, yard and storage.

```
Out(no_nliquid_housing_and_storage) P+
Out(no_nsolid_housing_and_storage);
```

n2o_nsolid_housing_and_storage Annual N2O emission from solid manure from housing, yard and storage.

```
Sum(n2o_nsolid, Livestock::OtherCattle::NxOx) P+
Sum(n2o_nsolid, Livestock::DairyCow::NxOx) P+
Sum(n2o_nsolid, Livestock::SmallRuminants::NxOx) P+
Sum(n2o_nsolid, Livestock::RoughageConsuming::NxOx) P+
Sum(n2o_nsolid, Livestock::Pig::NxOx) P+
Sum(n2o_nsolid, Livestock::FatteningPigs::NxOx) P+
Sum(n2o_nsolid, Livestock::Equides::NxOx) P+
Sum(n2o_npoultry, Livestock::Poultry::NxOx);
```

n2o_nliquid_housing_and_storage Annual N2O emission from liquid manure from housing, yard and storage.

```
Sum(n2o_nliquid, Livestock::OtherCattle::NxOx) P+
Sum(n2o_nliquid, Livestock::DairyCow::NxOx) P+
Sum(n2o_nliquid, Livestock::Pig::NxOx) P+
Sum(n2o_nliquid, Livestock::FatteningPigs::NxOx);
```

n2o_nhousing_and_storage Annual N2O emission from housing, yard and storage.

```
Out(n2o_nliquid_housing_and_storage) P+
Out(n2o_nsolid_housing_and_storage);
```

n2_ngrazing Annual NH3 emission from all grazing areas and Poultry grazing activities.

```
Sum(n2_ngrazing,Livestock::OtherCattle::Grazing) P+
Sum(n2_ngrazing,Livestock::DairyCow::Grazing) P+
Sum(n2_ngrazing,Livestock::Pig::Grazing) P+
Sum(n2_ngrazing,Livestock::FatteningPigs::Grazing) P+
Sum(n2_ngrazing,Livestock::Equides::Grazing) P+
Sum(n2_ngrazing,Livestock::SmallRuminants::Grazing) P+
Sum(n2_ngrazing,Livestock::RoughageConsuming::Grazing) P+
Sum(n2_ngrazing,Livestock::Poultry::Grazing);
```

no_ngrazing Annual NH3 emission from all grazing areas and Poultry grazing activities.

```
Sum(no_ngrazing,Livestock::OtherCattle::Grazing) P+
Sum(no_ngrazing,Livestock::DairyCow::Grazing) P+
Sum(no_ngrazing,Livestock::Pig::Grazing) P+
Sum(no_ngrazing,Livestock::FatteningPigs::Grazing) P+
Sum(no_ngrazing,Livestock::Equides::Grazing) P+
Sum(no_ngrazing,Livestock::SmallRuminants::Grazing) P+
Sum(no_ngrazing,Livestock::RoughageConsuming::Grazing) P+
Sum(no_ngrazing,Livestock::Poultry::Grazing);
```

n2o_ngrazing Annual NH3 emission from all grazing areas and Poultry grazing activities.

```
Sum(n2o_ngrazing,Livestock::OtherCattle::Grazing) P+
Sum(n2o_ngrazing,Livestock::DairyCow::Grazing) P+
Sum(n2o_ngrazing,Livestock::Pig::Grazing) P+
Sum(n2o_ngrazing,Livestock::FatteningPigs::Grazing) P+
Sum(n2o_ngrazing,Livestock::Equides::Grazing) P+
Sum(n2o_ngrazing,Livestock::SmallRuminants::Grazing) P+
Sum(n2o_ngrazing,Livestock::RoughageConsuming::Grazing) P+
Sum(n2o_ngrazing,Livestock::Poultry::Grazing);
```

n_remain_grazing Annual N remaining on pasture from all grazing areas.

```
Sum(n_remain_grazing, Livestock::OtherCattle::Grazing) P+
Sum(n_remain_grazing, Livestock::DairyCow::Grazing) P+
Sum(n_remain_grazing, Livestock::Pig::Grazing) P+
Sum(n_remain_grazing, Livestock::FatteningPigs::Grazing) P+
Sum(n_remain_grazing, Livestock::Equides::Grazing) P+
Sum(n_remain_grazing, Livestock::SmallRuminants::Grazing) P+
Sum(n_remain_grazing, Livestock::RoughageConsuming::Grazing) P+
Sum(n_remain_grazing, Livestock::Poultry::Grazing);
```

tan_remain_grazing Annual N remaining on pasture from all grazing areas.

```
Sum(tan_remain_grazing, Livestock::OtherCattle::Grazing) P+
Sum(tan_remain_grazing, Livestock::DairyCow::Grazing) P+
Sum(tan_remain_grazing, Livestock::Pig::Grazing) P+
Sum(tan_remain_grazing, Livestock::FatteningPigs::Grazing) P+
Sum(tan_remain_grazing, Livestock::Equides::Grazing) P+
Sum(tan_remain_grazing, Livestock::SmallRuminants::Grazing) P+
Sum(tan_remain_grazing, Livestock::RoughageConsuming::Grazing) P+
Sum(tan_remain_grazing, Livestock::Poultry::Grazing);
```

tan_remain_scrubber Annual N remaining on pasture from all grazing areas.

```
Sum(tan_air_scrubber, Livestock::Pig::Housing) P+
Sum(tan_air_scrubber, Livestock::FatteningPigs::Housing) P+
Sum(tan_air_scrubber, Livestock::Poultry::Housing);
```

2.2 Livestock::DairyCow::Excretion

This process calculates the annual N excretion (total N and Nsol (urea plus measured total ammoniacal nitrogen)) of a number of dairy cows as a function of the milk yield and the supplied feed ration. Nitrogen surpluses from increased nitrogen uptake are primarily excreted as Nsol in the urine. Eighty percent of the increased N excretion is therefore added to the Nsol fraction.

The standard N excretion was taken from the official Swiss fertilizer guidelines. These values were compiled on the basis of official feeding recommendations (RAP 1999) by a group of feeding experts under the lead of H. Menzi. Even though the methodology used is not documented in detail, it was well known to the authors of DYNAMO.

2.2.1 References:

Burgos SA, Robinson PH, Fadel JG, DePeters EJ 2005. Ammonia volatilization potential: Prediction of urinary urea nitrogen output on lactating dairy cows. Agriculture, Ecosystems and Environment 111:261-269.

Peterson SO, Sommer SG, Aaes O, Soegaard K 1998. Ammonia losses from urine and dung of grazing cattle: effect of N intake. Atmospheric environment 32:295-300.

RAP 1999. Fütterungsempfehlungen und Nährwerttabelle für Wiederkäuer. 4. Überarbeitete Auflage, 327p, Landwirtschaftliche Lehrmittelzentrale, Zollikofen.

Flisch R, Sinaj S, Charles R, Richner W 2009. Grundlagen für die die Düngung im Acker- und Futterbau. Agrarforschung 16(2).

Inputs

animalcategory Animal category

animals Number of dairy cows in barn.

dimensioning_barn Number of available animal places.

inp_n_excretion Annual standard N excretion for a dairy cow

tan_fraction TAN fraction of the annual standard N excretion

Outputs

animals Number of dairy cows in barn.

```
In(animals);
```

animalcategory Animal category

```
In(animalcategory);
```

n_excretion_animal Annual mean total N excreted per animal.

```
if ( (not defined In(inp_n_excretion)) or lc In(inp_n_excretion) eq 'standard' ) {
  Tech(standard_N_excretion) *
  Val(cmilk_yield, Excretion::CMilk) *
  Val(c_feed_ration, Excretion::CFeed);
} else {
  if ( (In(inp_n_excretion) < 0.7 * Tech(standard_N_excretion)) or
       (In(inp_n_excretion) > 1.3 * Tech(standard_N_excretion)) ) {
    writeLog({
        en => "The N excretion entered for dairy cows differs from the standard by more than 30%!",
        de => "Die eingegebene N-Ausscheidung für Milchkühe weicht um mehr als 30% vom Standard ab!",
        fr => "Les excrétions azotées saisies pour les vâches laitières s'écartent de plus de 30 % du standar
    });
  }
```

```
  In(inp_n_excretion);
};
```

n_excretion Annual total N excreted by the specified number of animals.

```
Out(n_excretion_animal) *
Out(animals);
```

tan_content TAN content (as fraction) of the dairy cow excretion.

```
if ( (not defined In(tan_fraction)) or lc In(tan_fraction) eq 'standard' ) {
  if ( (not defined In(inp_n_excretion)) or lc In(inp_n_excretion) eq 'standard' ) {
    return ( Tech(share_Nsol) - Tech(feed_influence_on_Nsol) ) / Val(c_feed_ration, Excretion::CFeed) +
      Tech(feed_influence_on_Nsol);
  } else {
    return Tech(share_Nsol);
  }
} else {
  my $tan = In(tan_fraction);
  $tan = In(tan_fraction) / 100;
  if ( abs($tan - Tech(share_Nsol)) > 0.2) {
    writeLog({
      en => "The TAN fraction of N excretion entered for diary cows differs from the standard by more than 20
      de => "Der eingegebene TAN Anteil der N Ausscheidung für Milchkühe weicht um mehr als 20% vom Standard
      fr => "La proportion du TAN des excrétions azotées saisies pour les vâches laitières s'écartent de plus
    });
  }
  return $tan;
}
```

tan_excretion Annual soluble N excreted by the specified number of animals.

```
Out(n_excretion) * Out(tan_content);
```

area_increase Factor on what barn size does increase the regularized minimal, limited to 0.5

```
if ( (Out(animals) < In(dimensioning_barn) ) and (Out(animals) != 0) ) {
  if ( In(dimensioning_barn) >= (Out(animals) * 1.5) ) {
    0.5;
  }
  else {
    In(dimensioning_barn) / Out(animals) - 1;
  }
}
else {
  0.0;
}
```

dimensioning_check Check if number of animals <= number of animal places.

```
if ( In(dimensioning_barn) < Out(animals) ) {
  writeLog({
    en => "The number of available animal places must be equal or higher than the number of animals.",
    de => "Anzahl Tierplätze muss grösser oder gleich der Anzahl der Tiere sein.",
    fr => "Le nombre de places dans l'étable doit être au moins égal au nombre d'animaux."
  });
  return "barn dimensioning too small";
}
else {
  return "barn dimensioning ok";
}
```

Technical Parameters

standard_N_excretion 112
: Annual standard N excretion for a dairy cow according to Flisch et al. (2009).

share_Nsol 0.55
: Nsol content of excreta. Derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

feed_influence_on_Nsol 1
Proportion of N (calculated from feed ration correction) excreted as Nsol. Derived from e.g. Peterson et al. (1998).

2.3 Livestock::DairyCow::Excretion::CMilk

This process describes the relationship between the milk yield and the N excretion. While the N excretion decreases by 10% per 1000 kg less milk yield below the standard milk yield, nitrogen excretion increases by 5% per 1000 kg more milk yield above the standard milk yield. This correction factor was taken from GRUDAF 2009. It was originally derived from excretion calculations for different milk yields ranging from 4000 to 10000 kg year-1. The lower increase of the nitrogen excretion above 6500 kg results from the increasing proportion of concentrate necessary to cover the energy requirement for yields above 6500 kg. It is thus increasingly possible to reduce the unbalance of energy and protein existing in virtually all rations with a high proportion of roughage.

2.3.1 References:

Flisch R, Sinaj S, Charles R, Richner W (Eds.) 2009. Grundlagen für die die Düngung im Acker- und Futterbau 2009 (GRUDAF), Agrarforschung 16.2.

Inputs

milk_yield Annual milk yield per dairy cow.

Outputs

milk_yield Milk yield.

```
In(milk_yield);
```

cmilk_yield Milk yield correction factor for annual N excretion.

```
if ( Out(milk_yield) > Tech(standard_milk_yield) ) {
  1 + (Out(milk_yield) - Tech(standard_milk_yield)) / 1000 * Tech(a_high);
}
else {
  1 + (Out(milk_yield) - Tech(standard_milk_yield)) / 1000 * Tech(a_low);
}
```

Technical Parameters

standard_milk_yield 7500
Annual standard milk yield per dairy cow.

a_high 0.05
For milk yield > standard milk yield

a_low 0.05
For milk yield < standard milk yield

2.4 Livestock::DairyCow::Excretion::CFeed

This process accounts for the fact, that special rations can result in higher or lower N excretions as compared to standard excretions from Flisch et al. (2009). A differentiated consideration of the duration of the summer and winter feeding period according to farm location (altitude etc.) is possible but was not implemented for the emission inventory.

2.4.1 References:

Flisch R, Sinaj S, Charles R, Richner W 2009. Grundlagen für die die Düngung im Acker- und Futterbau. Agrarforschung 16(2).

Outputs

c_feed_ration Feed ration correction factor for annual N excretion.

```
1 +
Val(c_summer_ration, CFeedSummerRatio) +
Val(c_winter_ration, CFeedWinterRatio) +
Val(c_concentrates_summer, CConcentrates) +
Val(c_concentrates_winter, CConcentrates);
```

2.5 Livestock::DairyCow::Excretion::CFeedSummerRatio

This process calculates the correction factor for N excretion during the summer feeding period as compared to the standard excretion values of Walther et al. (2001). The average feed ration considered for the standard excretion presented in Walther et al. (2001) was calculated as average of four summer and four winter standard rations using dsummer and dwinter mentioned above. To calculate the N excretion of farm-specific summer rations, excretions were calculated with the same model used by the authors of Walther et al. (2001) (based on official feeing recommendations (RAP 1999)) using proportions of the specific feed typically used on farms (expert assumptions). No correction was considered for grass and grass silage, because grass is used by virtually all farms during the summer feeding period und because the crude protein content of grass silage is not much lower than that of grass. The thus calculated summer excretions were then expressed as % of average excretions.

2.5.1 References:

RAP 1999. Fütterungsempfehlungen und Nährwerttabellen für Wiederkäuer. 4. überarbeitete Auflage. LMZ Zollikofen. Walther U, Ryser JP, Flisch R (Eds.) 2001. Grundlagen für die Düngung im Acker- und Futterbau 2001. Agrarforschung 8:1-80.

Inputs

share_hay_summer Proportion of animals receiving hay in summer.

share_maize_silage_summer Proportion of animals receiving maize silage in summer.

share_maize_pellets_summer Proportion of animals receiving maize pellets in summer.

Outputs

share_hay_summer Share

```
if (In(share_hay_summer) > 1) {
  In(share_hay_summer) / 100;
} else {
  In(share_hay_summer);
}
```

share_maize_silage_summer Share

```
if ( In(share_maize_silage_summer) > 1 ) {
  In(share_maize_silage_summer) / 100;
} else {
  In(share_maize_silage_summer);
}
```

share_maize_pellets_summer Share

```
if (In(share_maize_pellets_summer) > 1) {
   In(share_maize_pellets_summer) / 100;
} else {
   In(share_maize_pellets_summer);
}
```

share_grass_only_summer Share

```
if ( Out(share_hay_summer) >= Out(share_maize_silage_summer) and
     Out(share_hay_summer) >= Out(share_maize_pellets_summer) ) {
  1 - Out(share_hay_summer);
} elsif ( Out(share_maize_silage_summer) >= Out(share_hay_summer) and
          Out(share_maize_silage_summer) >= Out(share_maize_pellets_summer) ) {
  1 - Out(share_maize_silage_summer);
} else {
```

```
  1 - Out(share_maize_pellets_summer);
}
```

c_summer_ration Summer feed ration correction factor for annual N excretion.

```
Tech(c_hay_summer) * Out(share_hay_summer) +
Tech(c_maize_silage_summer) * Out(share_maize_silage_summer) +
Tech(c_maize_pellets_summer)  * Out(share_maize_pellets_summer) +
Tech(c_default_grass) * Out(share_grass_only_summer) ;
```

Technical Parameters

c_default_grass +0.05
Modification of annual N excretion by adding hay to the standard ration during the summer feeding period.

c_hay_summer +0.01
Modification of annual N excretion by adding hay to the standard ration during the summer feeding period.

c_maize_silage_summer -0.025
Modification of annual N excretion by adding maize silage to the standard ration during summer feeding period.

c_maize_pellets_summer -0.025
Modification of annual N excretion by adding maize pellets to the standard ration during summer feeding period.

2.6 Livestock::DairyCow::Excretion::CFeedWinterRatio

This process calculates the correction factor for the N excretion during the winter feeding period as compared to the standard excretion values of Walther et al. (2001). The average feed ration considered for the standard excretion presented in Walther et al. (2001) was calculated as average of four summer and four winter standard rations using dsummer and dwinter mentioned above. To calculate the N excretion of farm-specific winter rations, excretions were calculated with the same model used by the authors of Walther et al. (2001) (based on official feeding recommendations (RAP 1999)) using proportions of the specific feed typically used on farms (expert assumptions). No correction was considered for hay, because hay is used by virtually all farms during the winter feeding period. The thus calculated winter excretions were then expressed as % of average excretions.

2.6.1 References:

RAP 1999. Fütterungsempfehlungen und Nährwerttabellen für Wiederkäuer. 4. überarbeitete Auflage. LMZ Zollikofen. Walther U,Ryser JP, Flisch R (Eds.) 2001. Grundlagen für die Düngung im Acker- und Futterbau 2001. Agrarforschung 8:1-80.

Inputs

share_maize_silage_winter Proportion of animals receiving maize silage in winter.

share_grass_silage_winter Proportion of animals receiving grass silage in winter.

share_maize_pellets_winter Proportion of animals receiving maize pellets in winter.

share_potatoes_winter Proportion of animals receiving potatoes in winter.

share_beets_winter Proportion of animals receiving beets in winter.

Outputs

share_grass_silage_winter Share

```
if ( In(share_grass_silage_winter) > 1 ) {
  In(share_grass_silage_winter) / 100;
} else {
  In(share_grass_silage_winter);
}
```

share_maize_silage_winter Share

```
if ( In(share_maize_silage_winter) > 1 ) {
  In(share_maize_silage_winter) / 100;
} else {
  In(share_maize_silage_winter);
}
```

share_maize_pellets_winter Share

```
if ( In(share_maize_pellets_winter) > 1 ) {
  In(share_maize_pellets_winter) / 100;
} else {
  In(share_maize_pellets_winter);
}
```

share_potatoes_winter Share

```
if ( In(share_potatoes_winter) > 1 ) {
  In(share_potatoes_winter) / 100;
} else {
  In(share_potatoes_winter);
}
```

share_beets_winter Share

```
if ( In(share_beets_winter) > 1 ) {
  In(share_beets_winter) / 100;
} else {
  In(share_beets_winter);
}
```

share_hay_only_winter Share

```
if ( Out(share_grass_silage_winter) >= Out(share_maize_silage_winter) and
     Out(share_grass_silage_winter) >= Out(share_maize_pellets_winter) ) {
  1 - Out(share_grass_silage_winter);
} elsif ( Out(share_maize_silage_winter) >= Out(share_grass_silage_winter) and
          Out(share_maize_silage_winter) >= Out(share_maize_pellets_winter) ) {
  1 - Out(share_maize_silage_winter);
} else {
  1 - Out(share_maize_pellets_winter);
}
```

c_winter_ration Winter feed ration correction factor for annual N excretion.

```
Tech(c_grass_silage_winter) * Out(share_grass_silage_winter) +
Tech(c_maize_silage_winter) * Out(share_maize_silage_winter) +
Tech(c_maize_pellets_winter) * Out(share_maize_pellets_winter) +
Tech(c_potatoes_winter) * Out(share_potatoes_winter) +
Tech(c_beets_winter) * Out(share_beets_winter) +
Tech(c_default_hay) * Out(share_hay_only_winter);
```

Technical Parameters

c_default_hay -0.01
Modification of annual N excretion by adding grass silage to the standard ration during winter feeding period.

c_grass_silage_winter 0.03
Modification of annual N excretion by adding grass silage to the standard ration during winter feeding period.

c_maize_silage_winter -0.02
Modification of annual N excretion by adding maize silage to the standard ration during winter feeding period.

c_maize_pellets_winter -0.02
Modification of annual N excretion by adding maize pellets to the standard ration during winter feeding period.

c_potatoes_winter 0.00
Modification of annual N excretion by adding potatoes to the standard ration during the winter feeding period.

c_beets_winter 0.00
Modification of annual N excretion by adding beets to the standard ration during the winter feeding period.

2.7 Livestock::DairyCow::Excretion::CConcentrates

This formula takes into account the amount of concentrates used per cow during the winter and summer feeding period. The correction is based on the fact that concentrates (grains) can specifically balance the energy to protein ratio, thus reducing the crude protein.

2.7.1 References:

Flückiger E 1989. Stickstoff- und Mineralstoffumsatz von Milchkühen in Abhängigkeit von Rationentyp und Produktionsphase unter besonderer Berücksichtigung umweltrelevanter Aspekte. Diss ETH Nr 8865.

TODO (Harald Menzi): Confirm calculation, and standard ratios.

Inputs

amount_summer Amount of concentrates per animal per day in summer.

amount_winter Amount of concentrates per animal and per day in winter.

Outputs

amount_summer Amount of concentrates per animal and per day in summer

```
In(amount_summer);
```

amount_winter Amount of concentrates per animal and per day in winter

```
In(amount_winter);
```

c_concentrates_summer Calculation of correction to excretions with 0.3, 0.5, 1, 2, 3, 4, 6 kg of concentrate (barley and wheat) per cow per day, taking into account the amount of roghage substituted by the concentrate (according to the energy content) and the relative differnce of the protein content of the roughage and the concentrate. Results used to calculate a regression for % modification of N excretion due to concentrate quantity summer. Standard for Summer = 1 kg animal-1 day-1.

```
Tech(par_a_summer) + Tech(par_b_summer) * Out(amount_summer);
```

c_concentrates_winter Calculation of correction to excretions with 0.3, 0.5, 1, 2, 3, 4, 6 kg of concentrate (barley and wheat) per cow per day, taking into account the amount of roghage substituted by the concentrate (according to the energy content) and the relative differnce of the protein content of the roughage and the concentrate. Results used to calculate a regression for % modification of N excretion due to concentrate quantity summer. Standard for Winter = 2 kg animal-1 day-1.

```
Tech(par_a_winter) +  Tech(par_b_winter) * Out(amount_winter);
```

Technical Parameters

par_a_summer 0.0393
Parameter a of linear regression a + b*x.

par_b_summer -0.0197
Parameter a of linear regression a + b*x.

par_a_winter -0.0406
Parameter a of linear regression a + b*x.

par_b_winter 0.0145
Parameter b of linear regression a + b*x.

2.8 Livestock::DairyCow::Housing

This process calculates the NH3 emission in dairy cow housing depending on the N excretion and the housing systems. The NH3 emission is assumed to be proportional to the total N excretion of the animals because the contaminated surfaces will primarily drive emission, which will remain active even when animals are on the pasture or exercise yard.

A proportional correction is applied according to the area per animal.

A correction is applied if the part of the day grazing is above a defined grazing hours per days.

2.8.1 Definition of System boundaries for the housing Process:

For housing systems with integrated exercise yards, it is difficult to distinguish between emissions from housing, exercise yard and storage. For these housingtypes the emission may be only validated for the sum of housing, exercise yard and storage emission.

Outputs

n_into_housing Annual N flux into the house.

```
Val(n_excretion, Excretion) -
Val(n_into_grazing, Grazing) -
Val(n_into_yard, Yard);
```

tan_into_housing Annual N flux as TAN into the house.

```
     Val(tan_excretion, Excretion) -
 Val(tan_into_grazing, Grazing) -
 Val(tan_into_yard, Yard);
```

ef_nh3_nhousing NH3 emission factor for dairy cow housing systems.

```
my $ef_nh3 = Val(c_grazing, Housing::KGrazing) *
                Val(c_area, Housing::Type) *
                Val(er_housing, Housing::Type) *
                Val(c_housing_floor, Housing::Floor) *
                Val(c_free_factor_housing, Housing::CFreeFactor);
#FIXME: Check: Is it in any way even possible that $ef_nh3 > 1???
$ef_nh3 = 1 unless $ef_nh3 < 1;
return $ef_nh3;
```

nh3_nhousing Annual NH3 emission from dairy cow housing systems per animal place.

```
Out(tan_into_housing) * Out(ef_nh3_nhousing);
```

n_outhousing Annual N flux out of the housing.

```
Out(n_into_housing) - Out(nh3_nhousing);
```

tan_outhousing Annual N flux as TAN out of the housing.

```
Out(tan_into_housing) - Out(nh3_nhousing);
```

n_outhousing_liquid Annual N flux out of housing, slurry or liquid fraction of manure from dairy cows.

```
Out(n_outhousing) * Val(share_liquid, Housing::Type);
```

tan_outhousing_liquid Annual N flux as TAN out of housing, slurry or liquid fraction of manure from dairy cows.

```
Out(tan_outhousing) * Val(share_liquid, Housing::Type);
```

n_outhousing_solid Annual N flux out of housing from solid fraction of manure.

```
Out(n_outhousing) - Out(n_outhousing_liquid);
```

tan_outhousing_solid Annual N flux as TAN out of housing from solid fraction of manure.

```
Out(tan_outhousing) - Out(tan_outhousing_liquid);
```

2.9 Livestock::DairyCow::Housing::Type

This process selects the correction factor for the specific housing types for dairy cows. Among these correction factors are the emission rate for the housing type, the correction factor for the housing type area, the correction factor for the area per animal, the liquid and solid share for the housing type as well as the factor on what barn size increases the regularized minimal (limited to 0.5).

Inputs

housing_type Type of housing.

Outputs

housing_type Housing type (needed in other modules).

```
if ( not defined In(housing_type) ) {
  writeLog({
    en => "TODO: dairy cow input 'housing_type' not defined!",
    de => "TODO: dairy cow input 'housing_type' not defined!",
    fr => "TODO: dairy cow input 'housing_type' not defined!"
  });
}
In(housing_type);
```

k_area Correction factor for the housing type area.

```
given ( In(housing_type) ) {
  return Val(k_area,Type::Tied_Housing_Slurry)                   when 'Tied_Housing_Slurry';
  return Val(k_area,Type::Tied_Housing_Slurry_Plus_Solid_Manure)  when 'Tied_Housing_Slurry_Plus_Solid_Manure
  return Val(k_area,Type::Loose_Housing_Slurry)                  when 'Loose_Housing_Slurry';
  return Val(k_area,Type::Loose_Housing_Slurry_Plus_Solid_Manure) when 'Loose_Housing_Slurry_Plus_Solid_Manur
  return Val(k_area,Type::Loose_Housing_Deep_Litter)             when 'Loose_Housing_Deep_Litter';
}
```

er_housing Emission rate for the housing type.

```
given ( In(housing_type) ) {
  return Val(er_housing,Type::Tied_Housing_Slurry)                   when 'Tied_Housing_Slurry';
  return Val(er_housing,Type::Tied_Housing_Slurry_Plus_Solid_Manure)  when 'Tied_Housing_Slurry_Plus_Solid_Ma
  return Val(er_housing,Type::Loose_Housing_Slurry)                  when 'Loose_Housing_Slurry';
  return Val(er_housing,Type::Loose_Housing_Slurry_Plus_Solid_Manure) when 'Loose_Housing_Slurry_Plus_Solid_M
  return Val(er_housing,Type::Loose_Housing_Deep_Litter)             when 'Loose_Housing_Deep_Litter';
}
```

share_liquid Liquid share for the housing type.

```
given ( In(housing_type) ) {
  return Val(share_liquid,Type::Tied_Housing_Slurry)                   when 'Tied_Housing_Slurry';
  return Val(share_liquid,Type::Tied_Housing_Slurry_Plus_Solid_Manure)  when 'Tied_Housing_Slurry_Plus_Solid_
  return Val(share_liquid,Type::Loose_Housing_Slurry)                  when 'Loose_Housing_Slurry';
  return Val(share_liquid,Type::Loose_Housing_Slurry_Plus_Solid_Manure) when 'Loose_Housing_Slurry_Plus_Solic
  return Val(share_liquid,Type::Loose_Housing_Deep_Litter)             when 'Loose_Housing_Deep_Litter';
}
```

c_area Correction factor for area per animal.

```
1 + (Val(area_increase, ..::Excretion) * Out(k_area));
```

2.10 Livestock::DairyCow::Housing::Type::Tied_Housing_Slurry

This process describes the correction factors for the tied housing slurry system for dairy cows such as the housing specific emission rate, the area per animal correction, the liquid share and solid share.

Outputs

er_housing Emission rate for specific housing type.

```
Tech(er);
```

share_liquid Part of Ntot flowing into liquid storage for selected housing type.

```
Tech(share_liquid);
```

k_area Correction factor for area per animal.

```
Tech(k_area);
```

Technical Parameters

er 0.067
Emission rate for the tied housing slurry system for dairy cows. According to the consensus obtained in the workshop at ART Tänikon 02/11/07: 4% Ntot; converted using Nsol of 60% and the emission rate of 6.7% based on TAN.

share_liquid 1
For the tied housing slurry system 100% of the manure goes into the liquid fraction of the storage/application.

k_area 0
Additional surfaces are not used.

2.11 Livestock::DairyCow::Housing::Type::Tied_Housing_Slurry_Plus_Solid_Manure

This process describes the correction factors for the tied housing liquid solid system for dairy cows such as the housing specific emission rate, the area per animal correction, the liquid share and solid share.

Outputs

er_housing Emission rate for specific housing type.

```
Tech(er);
```

share_liquid Part of Ntot flowing into liquid storage for selected housing type.

```
Tech(share_liquid);
```

k_area Correction factor for area per animal.

```
Tech(k_area);
```

Technical Parameters

er 0.067
Emission rate for the tied housing liquid solid system for dairy cows. According to the consensus obtained in the workshop at ART Tänikon 02/11/07: 4% Ntot, converted using Nsol of 60% and the emission rate of 6.7% based on TAN.

share_liquid 0.57
For the tied housing liquid solid system 57% of the manure goes into the liquid fraction of the storage/application.

k_area 0
Additional surfaces are not used.

2.12 Livestock::DairyCow::Housing::Type::Loose_Housing_Slurry

This process describes the correction factors for the loose housing slurry system for dairy cows such as the housing specific emission rate, the area per animal correction, the liquid share and solid share.

2.12.1 References:

UNECE 2007. Guidance document on control techniques for preventing and abating emissions of ammonia. UNECE executive body for the convention on long-range transboundary air pollution, Working Group on Strategies and Review, EB.AIR/WH.5/2007/13/ 16 July 2007, Genf. 35p.

Outputs

er_housing Emission rate for specific housing type.

```
Tech(er);
```

share_liquid Part of Ntot flowing into liquid storage for selected housing type.

```
Tech(share_liquid);
```

k_area Correction factor for area per animal.

```
Tech(k_area);
```

Technical Parameters

er 0.183

Emission rate for the loose housing slurry system for dairy cows. According to the consensus obtained in the workshop at ART Tänikon 02/11/07: 11% Ntot; converted using Nsol of 60% and the emission rate of 18.3% based on TAN. Reference value UNECE(2007): 11 kg HN3 = 8% TAN.

share_liquid 1

For the loose housing slurry system 100% of the manure goes into the liquid fraction of the storage/application.

k_area 0.5

According to the consensus obtained in the workshop at ART Tänikon 02/11/07: it is assumed that additional surfaces are entirely used since barriers are hardly fea-sible. The emission is increased by 5% per 10% of additional surfaces up to a maximum of 50% additional surface.

2.13 Livestock::DairyCow::Housing::Type::Loose_Housing_Slurry_Plus_Solid_Manure

This process describes the correction factors for the loose housing liquid solid system for dairy cows such as the housing specific emission rate, the area per animal correction, the liquid share and solid share.

2.13.1 References:

UNECE 2007. Guidance document on control techniques for preventing and abating emissions of ammonia. UNECE executive body for the convention on long-range transboundary air pollution, Working Group on Strategies and Review, EB.AIR/WH.5/2007/13/ 16 July 2007, Genf. 35p.

Outputs

er_housing Emission rate for specific housing type.

```
Tech(er);
```

share_liquid Part of Ntot flowing into liquid storage for selected housing type.

```
Tech(share_liquid);
```

k_area Correction factor for area per animal.

```
Tech(k_area);
```

Technical Parameters

er 0.183
Emission rate for the loose housing liquid solid system for dairy cows. According to the consensus obtained in the workshop at ART Tänikon 02/11/07: 11% Ntot; converted using Nsol of 60% and the emission rate of 18.3% based on TAN. Reference value UNECE(2007): 11 kg NH3 = 8% TAN.

share_liquid 0.57
For the loose housing liquid-solid system 57% of the N of the manure goes into the liquid manure storage.

k_area 0.5
According to the consensus obtained in the workshop at ART Tänikon 02/11/07: it is assumed that additional surfaces are entirely used since barriers are hardly fea-sible. The emission is increased by 5% per 10% of additional surfaces up to a maximum of 50% additional surface.

2.14 Livestock::DairyCow::Housing::Type::Loose_Housing_Deep_Litter

This process describes the correction factors for the loose housing deep litter system for dairy cows such as the housing specific emission rate, the area per animal correction, the liquid share and solid share.

2.14.1 References:

UNECE 2007. Guidance document on control techniques for preventing and abating emissions of ammonia. UNECE executive body for the convention on long-range transboundary air pollution, Working Group on Strategies and Review, EB.AIR/WH.5/2007/13/ 16 July 2007, Genf. 35p.

Outputs

er_housing Emission rate for specific housing type.

```
Tech(er);
```

share_liquid Part of Ntot flowing into liquid storage for selected housing type.

```
Tech(share_liquid);
```

k_area Correction factor for area per animal.

```
Tech(k_area);
```

Technical Parameters

er 0.183

Emission rate for the loose housing deep litter system for dairy cows. According to the consensus obtained in the workshop at ART Tänikon 02/11/07: 11% Ntot; convered using Nsol of 60% and the emission rate of 18.3% based on TAN. Reference value UNECE(2007): 11 kg NH3 = 8% TAN.

share_liquid 0

For the loose housing deep litter system 100% of the manure goes into the solid manure storage/application.

k_area 0.5

According to the consensus obtained in the workshop at ART Tänikon 02/11/07: it is assumed that additional surfaces are entirely used since barriers are hardly fea-sible. The emission is increased by 5% per 10% of additional surfaces up to a maximum of 50% additional surface.

2.15 Livestock::DairyCow::Housing::Floor

This submodul calculates the annual NH3 reduction due to a grooved floor in housing systems according to the UNECE guideline 2007.

2.15.1 References

UNECE 2007. Guidance document on control techniques for preventing and abating emissions of ammonia. ECE/EB.AIR/WG.5/2007/13.

Inputs

mitigation_housing_floor Mitigation options for loose housing systems for cattle.

Outputs

c_housing_floor Correction factor for the emission due to the use of a grooved floor in housing systems.

```
return 1 unless defined In(mitigation_housing_floor);
given ( In(mitigation_housing_floor) ) {
  when 'raised_feeding_stands' {
    if ( (Val(housing_type, Type) eq 'Loose_Housing_Slurry') or
        (Val(housing_type, Type) eq 'Loose_Housing_Slurry_Plus_Solid_Manure') ) {
      1 - Tech(red_raised_feeding_stands);
    } else {
      1;
    }
  }
  when 'floor_with_cross_slope_and_collection_gutter' {
    if ( Val(housing_type, Type) eq 'Loose_Housing_Slurry' ) {
      1 - Tech(red_floor_with_cross_slope_and_collection_gutter);
    } else {
      1;
    }
  }
  when 'floor_with_cross_slope_and_collection_gutter_and_raised_feeding_stands' {
    if ( Val(housing_type, Type) eq 'Loose_Housing_Slurry' ) {
      1 - Tech(red_floor_with_cross_slope_and_collection_gutter_and_raised_feeding_stands);
    } else {
      1;
    }
  }
  default {
    # add when "none" & default Warning!
    1;
  }
}
```

Technical Parameters

red_raised_feeding_stands 0.1
Reduction efficiency as compared to cubicle house (UNECE 2007, paragraph 57, table 4).

red_floor_with_cross_slope_and_collection_gutter 0.2
Reduction efficiency as compared to cubicle house (UNECE 2007, paragraph 57, table 4).

red_floor_with_cross_slope_and_collection_gutter_and_raised_feeding_stands 0.3
Reduction efficiency as compared to cubicle house (UNECE 2007, paragraph 57, table 4).

2.16 Livestock::DairyCow::Housing::CFreeFactor

TODO

Inputs

free_correction_factor Factor to define free.

Outputs

c_free_factor_housing Free correction factor for NH3 housing emission.

```
if ( In(free_correction_factor) // 0 != 0 ) {
  writeLog({
    en => "You have entered an additional emission mitigation measure for a dairy cows housing of"
          . In(free_correction_factor) . "%\!\n" ,
    de => "Sie haben eine zusätzliche emissionsmindernde Massnahme für einen Stall der Milchkühe von "
          . In(free_correction_factor) . "\% eingegeben!\n" ,
    fr => "Vous avez introduit une mesure supplémentaire limitant les émissions provenant d'une "
          . "stabulation pour vâches laitières de " . In(free_correction_factor) . "\% !\n"
  });
  return 1 - In(free_correction_factor) / 100;
}
else {
  return 1;
}
```

2.17 Livestock::DairyCow::Housing::KGrazing

This process calculates the correction factor for the non proportional change of the housing emission according to the grazing hours per day. Source is Phillips et al. (1998) and Gilhespy et al. (2006) empirical estimation was done by Thomas Kupper.

Outputs

c_grazing The correction factor for the reduction of the housing emission depending on the number of grazing hours per day and the grazing days per year.

```
my $k_grazing = Tech(k_grazing_a) * exp(Tech(k_grazing_b) * Val(grazing_hours, ..::Outdoor));
# scale with ratio grazing_days per year
($k_grazing - 1) * Val(grazing_days, ..::Outdoor) / 365 + 1;
```

Technical Parameters

k_grazing_a 0.9989
Coefficient a of empirical estimation c = a * exp(b * grazing_hours).

k_grazing_b 0.0403
Coefficient a of empirical estimation c = a * exp(b * grazing_hours).

2.18 Livestock::DairyCow::Outdoor

Input parameters for exercise yard and grazing.

Inputs

yard_days Access to exercise yard in days per year.

exercise_yard Exercise yard: not available, available: roughage is not supplied in the exercise yard, available: roughage is partly supplied in the exercise yard, available: roughage is exclusively supplied in the exercise yard.

floor_properties_exercise_yard Floor properties(solid floor, unpaved floor, perforated floor, paddock or pasture used as exercise yard).

free_correction_factor Factor to define free ?

grazing_days Average grazing days per year.

grazing_hours Average grazing hours per day.

Outputs

yard_days Yard days per year.

```
In(yard_days);
```

exercise_yard Exercise yard type.

```
In(exercise_yard);
```

floor_properties_exercise_yard Exercise yard floor properties.

```
In(floor_properties_exercise_yard);
```

c_free_factor_yard Free reduction of the Emission rate for the Yard.

```
if ( In(free_correction_factor) // 0 != 0 ) {
  writeLog({
    en => "You have entered an additional emission mitigation measure for a dairy cows exercise yard of "
          . In(free_correction_factor) . "\%!\n",
    de => "Sie haben eine zusätzliche emissionsmindernde Massnahme für einen Laufhof der Milchkühe von "
          . In(free_correction_factor) . "\% eingegeben!\n",
    fr => "Vous avez introduit une mesure supplémentaire limitant les émissions provenant d'un parcours "
          . "extérieur pour vâches laitières de " . In(free_correction_factor) . "\% !\n"
  });
  return 1 - In(free_correction_factor) / 100;
} else {
  return 1;
}
```

grazing_hours Grazing hours per day.

```
In(grazing_hours);
```

grazing_days Grazing days per year.

```
In(grazing_days);
```

days_with_grazing_and_yard Number of Days whith access to yard and pasture

```
if( (Out(grazing_days) + Out(yard_days)) > 365 ){
  return Out(grazing_days) + Out(yard_days) - 365;
} else {
  return 0;
}
```

2.19 Livestock::DairyCow::Yard

Outputs

c_floor_properties_exercise_yard Correction factor for the emission due to the use of the floor properties in housing systems.

```
given ( Val(floor_properties_exercise_yard, Outdoor) ) {
  when 'solid_floor' {
    1 - Tech(red_floor_properties_solid_floor);
  }
  when 'unpaved_floor' {
    1 - Tech(red_floor_properties_unpaved_floor);
  }
  when 'perforated_floor' {
    1 - Tech(red_floor_properties_perforated_floor);
  }
  when 'paddock_or_pasture_used_as_exercise_yard' {
    1 - Tech(red_floor_properties_paddock_or_pasture_used_as_exercise_yard);
  }
  default {
    1;
  }
}
```

share_excretion Share of excretion on the yard according the stay on yard. If the basic feeding is on the yard the share_basicfeeding is assumed. Otherwise the share is selected according to the access.

```
given ( Val(exercise_yard, Outdoor) ) {
  when 'available_roughage_is_not_supplied_in_the_exercise_yard' {
    Tech(share_available_roughage_is_not_supplied_in_the_exercise_yard);
  }
  when 'available_roughage_is_partly_supplied_in_the_exercise_yard' {
    Tech(share_available_roughage_is_partly_supplied_in_the_exercise_yard);
  }
  when 'available_roughage_is_exclusively_supplied_in_the_exercise_yard' {
    Tech(share_available_roughage_is_exclusively_supplied_in_the_exercise_yard);
  }
  when 'not_available' {
    0;
  }
}
```

share_excretion_with_grazing Share of excretion on the yard according the stay on yard with parallel acess to Pasture. If the basic feeding is on the yard the share_basicfeeding is assumed. Otherwise the share is selected according to the access.

```
if( (Val(days_with_grazing_and_yard, Outdoor) > 0) and
    (Out(share_excretion) > Tech(share_available_roughage_is_partly_supplied_in_the_exercise_yard)) ){
  writeLog({
    en => "The category \"roughage is exclusively supplied in the exercise yard\" is not compatible with the
    de => "Verabreichung von Grundfutter ausschliesslich auf dem Laufhof ist nicht möglich mit den eingegeben
    fr => "La distribution de fourrage exclusivement dans le parcours extérieur "
          . "pour les vâches laitières n'est pas possible pendant les jours de pâturage !\n",
  });
  return Tech(share_available_roughage_is_partly_supplied_in_the_exercise_yard);
} else {
  return Out(share_excretion);
}
```

n_into_yard Annual N excretion on yard for a defined animal category.

```
Val(n_excretion, Excretion) *
(
  # yard only (100%)
  Out(share_excretion) *
  (Val(yard_days, Outdoor) - Val(days_with_grazing_and_yard, Outdoor)) / 365 +
```

```
  # yard and grazing (share yard)
  Out(share_excretion_with_grazing) *
  Val(days_with_grazing_and_yard, Outdoor) / 365
);
```

tan_into_yard Annual soluble N excretion on yard for a defined animal category.

```
Val(tan_excretion,Excretion) *
(
  # yard only (100%)
  Out(share_excretion) *
  (Val(yard_days, Outdoor) - Val(days_with_grazing_and_yard, Outdoor)) / 365 +
  # yard and grazing (share yard)
  Out(share_excretion_with_grazing) *
  Val(days_with_grazing_and_yard, Outdoor) / 365
);
```

ef_nh3_nyard NH3 emission factor for dairy cow yard.

```
Tech(er_yard) *
Out(c_floor_properties_exercise_yard) *
Val(c_free_factor_yard, Outdoor);
```

nh3_nyard Annual NH3 emission from yard.

```
Out(tan_into_yard) *
Out(ef_nh3_nyard);
```

n_outyard_liquid Annual N flux from liquid part out of yard.

```
Out(n_into_yard) - Out(nh3_nyard);
```

tan_outyard_liquid Annual N flux as TAN from liquid part out of yard into storage.

```
Out(tan_into_yard) - Out(nh3_nyard);
```

n_outyard_solid Annual N flux from solid part out of yard.

```
0;
```

tan_outyard_solid Annual N flux as TAN from solid part out of yard into storage.

```
0;
```

Technical Parameters

er_yard 0.7
Emission rate for TAN on yard.

share_available_roughage_is_exclusively_supplied_in_the_exercise_yard 0.6
Share of excretion per day for animals with roughage exclusively on the yard.

share_available_roughage_is_partly_supplied_in_the_exercise_yard 0.2
Share of excretion per day for animals with roughage partly on the yard.

share_available_roughage_is_not_supplied_in_the_exercise_yard 0.1
Share of excretion per day for animals with roughage not supplied in the yard.

red_floor_properties_solid_floor 0.0
Reduction efficiency according to Reidy and Menzi.

red_floor_properties_unpaved_floor 0.5
Reduction efficiency according to Reidy and Menzi.

red_floor_properties_perforated_floor 0.75
Reduction efficiency according to Reidy and Menzi.

red_floor_properties_paddock_or_pasture_used_as_exercise_yard 0.9
Reduction efficiency according to Reidy and Menzi.

2.20 Livestock::DairyCow::Grazing

This process calculates the annual NH3 emission from grazing dairy cows based on the total N excreted on the pastures. The N excreted is calculated according to the time the animals spend on the pasture. It assumes that the excretions on the pasture are proportional to the time the animals are grazed.

2.20.1 References:

Bussink DW 1992. Ammonia volatilization from grassland receiving nitrogen fertilizer and rotationally grazed by dairy cattle. Fertilizer Research 33:257-265.

Bussink DW 1994. Relationship between ammonia volatilization and nitrogen fertilizer application rate, intake and excretion of herbage nitrogen by cattle on grazed swards. Fertilizer Research 38:111-121.

Jarvis SC, Hatch DJ, Lockyer DR 1989. Ammonia fluxes from grazed grassland: annual losses from cattle production systems and their relation to nitrogen inputs. Journal of Agricultural Science 113:99-108.

Peterson SO, Sommer SG, Aaes O, Soegaard K 1998. Ammonia losses from urine and dung of grazing cattle: effect of N intake. Atmospheric environment 32:295-300.

Ross CA, Jarvis SC 2001. Measurement of emission and deposition pattern of ammonia from urine in grass swards. Atmospheric environment 35:867-875.

Outputs

n_into_grazing Annual total N excretion during grazing for dairy cows.

```
Val(n_excretion, Excretion) *
Val(grazing_hours, Outdoor) / 24 *
(
  # grazing only (100%)
  (Val(grazing_days, Outdoor) - Val(days_with_grazing_and_yard, Outdoor)) / 365 +
  # shared grazing(+housing) and yard (100% - share yard)
  # this part is split between grazing and housing by the parts grazing_hours & residual
  (1 - Val(share_excretion_with_grazing, Yard)) *
  Val(days_with_grazing_and_yard, Outdoor) / 365
);
```

tan_into_grazing Annual soluble N (TAN) excretion during grazing for dairy cows.

```
Val(tan_excretion, Excretion) *
Val(grazing_hours, Outdoor) / 24 *
(
  # grazing only (100%)
  (Val(grazing_days, Outdoor) - Val(days_with_grazing_and_yard, Outdoor)) / 365 +
  # shared grazing(+housing) and yard (100% - share yard)
  # this part is split between grazing and housing by the parts grazing_hours & residual
  (1 - Val(share_excretion_with_grazing, Yard)) *
  Val(days_with_grazing_and_yard, Outdoor) / 365
);
```

ef_nh3_ngrazing Annual total NH3 emission from all grazing dairy cows.

```
Tech(er_dairycow_grazing);
```

nh3_ngrazing Annual total NH3 emission from all grazing dairy cows.

```
Out(tan_into_grazing) * Out(ef_nh3_ngrazing);
```

n2_ngrazing Annual total N2 emission from all grazing dairy cows.

```
Out(n_into_grazing) * Tech(er_n2_dairycow_grazing);
```

no_ngrazing Annual total N2 emission from all grazing dairy cows.

```
Out(n_into_grazing) * Tech(er_no_dairycow_grazing);
```

n2o_ngrazing Annual total N2O emission from all grazing dairy cows.

```
Out(n_into_grazing) * Tech(er_n2o_dairycow_grazing);
```

n_remain_grazing Annual N input on pasture.

```
Out(n_into_grazing) -
Out(nh3_ngrazing) -
Out(n2_ngrazing) -
Out(no_ngrazing) -
Out(n2o_ngrazing);
```

tan_remain_grazing Annual N input on pasture.

```
Out(tan_into_grazing) -
Out(nh3_ngrazing) -
Out(n2_ngrazing) -
Out(no_ngrazing) -
Out(n2o_ngrazing);
```

Technical Parameters

er_dairycow_grazing 0.083

Emission rate for the calculation of the annual NH3 emission during grazing for dairy cows. 5% Ntot (conversion with a portion of Nsol of 60%: EF 8.3% TAN; value based on Table 1 (Mean emission rate of 3.1% N excreted; range: 1.6-5.7% for grazing cows on a sward fertilized with 250 kg N/y) of Bussink (1992) and Table 3 (Mean emission rate of 3.3% N excreted; range: 0.0-7.4% for grazing cows on a sward fertilized with 250 kg N/y) of Bussink (1994)). The corresponding value is rather lower for Switzerland since the level of fertilization is lower resulting in a lower level for crude protein. The N level in the fodder of the sward fertilized with 250 kg N/y (31 g/kg d.m.; Table 4) is comparable to values common for Switzerland (Bussink (1994)). The EF chosen includes a safety margin.

er_n2_dairycow_grazing 0.0

Emission rate for manure application. Not considerd relevant

er_no_dairycow_grazing 0.0055

Emission rate for manure application. Stehfest, Bouwman 2006

er_n2o_dairycow_grazing 0.02

Emission rate for manure application. ICCP 2006: v4_11Ch_11; Tab11.1

2.21 Livestock::DairyCow::NxOx

TODO!

Outputs

er_n2_nsolid Annual N2 emissions from dairy cows housing, yard and grazing (production).

```
given ( Val(housing_type, Housing::Type) ) {
  return Tech(er_n2_solid_Slurry)                    when 'Tied_Housing_Slurry';
  return Tech(er_n2_solid_Slurry_Plus_Solid_Manure)  when 'Tied_Housing_Slurry_Plus_Solid_Manure';
  return Tech(er_n2_solid_Slurry)                    when 'Loose_Housing_Slurry';
  return Tech(er_n2_solid_Slurry_Plus_Solid_Manure)  when 'Loose_Housing_Slurry_Plus_Solid_Manure';
  return Tech(er_n2_solid_Solid)                     when 'Loose_Housing_Deep_Litter';
  default { return 0; }
};
```

er_no_nsolid Annual N2 emissions from dairy cows housing, yard and grazing (production).

```
given ( Val(housing_type, Housing::Type) ) {
  return Tech(er_no_solid_Slurry)                    when 'Tied_Housing_Slurry';
  return Tech(er_no_solid_Slurry_Plus_Solid_Manure)  when 'Tied_Housing_Slurry_Plus_Solid_Manure';
  return Tech(er_no_solid_Slurry)                    when 'Loose_Housing_Slurry';
  return Tech(er_no_solid_Slurry_Plus_Solid_Manure)  when 'Loose_Housing_Slurry_Plus_Solid_Manure';
  return Tech(er_no_solid_Solid)                     when 'Loose_Housing_Deep_Litter';
  default { return 0; }
};
```

er_n2o_nsolid Annual N2 emissions from dairy cows housing, yard and grazing (production).

```
given ( Val(housing_type, Housing::Type) ) {
  return Tech(er_n2o_solid_Slurry)                    when 'Tied_Housing_Slurry';
  return Tech(er_n2o_solid_Slurry_Plus_Solid_Manure)  when 'Tied_Housing_Slurry_Plus_Solid_Manure';
  return Tech(er_n2o_solid_Slurry)                    when 'Loose_Housing_Slurry';
  return Tech(er_n2o_solid_Slurry_Plus_Solid_Manure)  when 'Loose_Housing_Slurry_Plus_Solid_Manure';
  return Tech(er_n2o_solid_Solid)                     when 'Loose_Housing_Deep_Litter';
  default { return 0; }
};
```

er_n2_nliquid Annual N2 emissions from dairy cows housing, yard and grazing (production).

```
given ( Val(housing_type, Housing::Type) ) {
  return Tech(er_n2_liquid_Slurry)                    when 'Tied_Housing_Slurry';
  return Tech(er_n2_liquid_Slurry_Plus_Solid_Manure)  when 'Tied_Housing_Slurry_Plus_Solid_Manure';
  return Tech(er_n2_liquid_Slurry)                    when 'Loose_Housing_Slurry';
  return Tech(er_n2_liquid_Slurry_Plus_Solid_Manure)  when 'Loose_Housing_Slurry_Plus_Solid_Manure';
  return Tech(er_n2_liquid_Solid)                     when 'Loose_Housing_Deep_Litter';
  default { return 0; }
};
```

er_no_nliquid Annual N2 emissions from dairy cows housing, yard and grazing (production).

```
given ( Val(housing_type, Housing::Type) ) {
  return Tech(er_no_liquid_Slurry)                    when 'Tied_Housing_Slurry';
  return Tech(er_no_liquid_Slurry_Plus_Solid_Manure)  when 'Tied_Housing_Slurry_Plus_Solid_Manure';
  return Tech(er_no_liquid_Slurry)                    when 'Loose_Housing_Slurry';
  return Tech(er_no_liquid_Slurry_Plus_Solid_Manure)  when 'Loose_Housing_Slurry_Plus_Solid_Manure';
  return Tech(er_no_liquid_Solid)                     when 'Loose_Housing_Deep_Litter';
  default { return 0; }
};
```

er_n2o_nliquid Annual N2 emissions from dairy cows housing, yard and grazing (production).

```
given ( Val(housing_type, Housing::Type) ) {
  return Tech(er_n2o_liquid_Slurry)                    when 'Tied_Housing_Slurry';
  return Tech(er_n2o_liquid_Slurry_Plus_Solid_Manure)  when 'Tied_Housing_Slurry_Plus_Solid_Manure';
  return Tech(er_n2o_liquid_Slurry)                    when 'Loose_Housing_Slurry';
  return Tech(er_n2o_liquid_Slurry_Plus_Solid_Manure)  when 'Loose_Housing_Slurry_Plus_Solid_Manure';
  return Tech(er_n2o_liquid_Solid)                     when 'Loose_Housing_Deep_Litter';
```

```
    default { return 0; }
  };
```

n2_nsolid FIX: Annual N2 emissions from dairy cows housing, yard and storage.

```
( Val(n_into_housing, Housing) * (1 - Val(share_liquid, Housing::Type) )
) * Out(er_n2_nsolid);
```

no_nsolid FIX: Annual NO emissions from dairy cows housing, yard and grazing (production).

```
( Val(n_into_housing, Housing) * (1 - Val(share_liquid, Housing::Type) )
) * Out(er_no_nsolid);
```

n2o_nsolid FIX: Annual N2O emissions from dairy cows housing, yard and grazing (production).

```
( Val(n_into_housing, Housing) * (1 - Val(share_liquid, Housing::Type) )
) * Out(er_n2o_nsolid);
```

n2_nliquid FIX: Annual N2 emissions from dairy cows housing, yard and grazing (production).

```
( Val(n_into_housing, Housing) * Val(share_liquid, Housing::Type)  +
  Val(n_into_yard, Yard)
) * Out(er_n2_nliquid);
```

no_nliquid FIX: Annual NO emissions from dairy cows housing, yard and grazing (production).

```
( Val(n_into_housing, Housing) * Val(share_liquid, Housing::Type)  +
  Val(n_into_yard, Yard)
) * Out(er_no_nliquid);
```

n2o_nliquid FIX: Annual N2O emissions from dairy cows housing, yard and grazing (production).

```
( Val(n_into_housing, Housing) * Val(share_liquid, Housing::Type)  +
  Val(n_into_yard, Yard)
) *  Out(er_n2o_nliquid);
```

Technical Parameters

er_n2_solid_Slurry 0.0
Emission rate for N2 based on Ntot

er_n2_solid_Slurry_Plus_Solid_Manure 0.025
Emission rate for N2 based on Ntot

er_n2_solid_Solid 0.05
Emission rate for N2 based on Ntot

er_n2_liquid_Slurry 0.02
Emission rate for N2 based on Ntot

er_n2_liquid_Slurry_Plus_Solid_Manure 0.02
Emission rate for N2 based on Ntot

er_n2_liquid_Solid 0.05
Emission rate for N2 based on Ntot

er_no_solid_Slurry 0.002
Emission rate for NO based on Ntot

er_no_solid_Slurry_Plus_Solid_Manure 0.005
Emission rate for N2 based on Ntot

er_no_solid_Solid 0.01
Emission rate for NO based on Ntot

er_no_liquid_Slurry 0.002
Emission rate for NO based on Ntot

er_no_liquid_Slurry_Plus_Solid_Manure 0.002
Emission rate for NO based on Ntot

er_no_liquid_Solid 0.01
Emission rate for NO based on Ntot

er_n2o_solid_Slurry 0.005
Emission rate for N2O based on Ntot

er_n2o_solid_Slurry_Plus_Solid_Manure 0.005
Emission rate for N2O based on Ntot

er_n2o_solid_Solid 0.01
Emission rate for N2O based on Ntot

er_n2o_liquid_Slurry 0.002
Emission rate for N2O based on Ntot

er_n2o_liquid_Slurry_Plus_Solid_Manure 0.002
Emission rate for N2O based on Ntot

er_n2o_liquid_Solid 0.01
Emission rate for N2O based on Ntot

2.22 Livestock::OtherCattle::Excretion

This process calculates the annual N excretion of a number of cattle as a function of the supplied feed ration. The standard N excretion was taken from the official Swiss fertilizer guidelines. The Nsol content of the excreta is based on e.g. Peterson et al. (1998) or Burgos et al. (2005). These values were compiled on the basis of official feeding recommendations (Flisch et al. 2009) by H. Menzi. A detailed documentation will be prepared in the framework of the new revision of the document in the course of summer 2007.

2.22.1 References:

Burgos SA, Robinson PH, Fadel JG, DePeters EJ 2005. Ammonia volatilization potential: Prediction of urinary urea nitrogen output on lactating dairy cows. Agriculture, Ecosystems and Environment 111:261-269.

Peterson SO, Sommer SG, Aaes O, Soegaard K 1998. Ammonia losses from urine and dung of grazing cattle: effect of N intake. Atmospheric environment 32:295-300.

Flisch R, Sinaj S, Charles R, Richner W 2009. Grundlagen für die die Düngung im Acker- und Futterbau. Agrarforschung 16(2).

Inputs

animalcategory Animal category (suckling cows, 1 year old heifers, 2 years old heifers, 3 years old heifers, fattening calves, calves of suckling cows, beef cattle).

animals Number of animals for the selected type in barn.

dimensioning_barn Number of available animal places.

inp_n_excretion Annual standard N excretion for a dairy cow

tan_fraction TAN fraction of the annual standard N excretion

Outputs

animals Number of animals for the selected cattle category in barn.

```
In(animals);
```

animalcategory Animal category

```
In(animalcategory);
```

n_excretion_animal Annual total N excreted per animal.

```
my $cat = Out(animalcategory);
my $key = 'standard_N_excretion_' . $cat;
my $exc = $TE->{$key};
$exc = In(inp_n_excretion) unless ( (not defined In(inp_n_excretion)) or lc In(inp_n_excretion) eq 'standard'
if ( ($exc < 0.7 * $TE->{$key}) or ($exc > 1.3 * $TE->{$key})) {
  writeLog({
        en => "The N excretion entered for other cattle differs from the standard by more than 30%!",
        de => "Die eingegebene N-Ausscheidung für übriges Rindvieh weicht um mehr als 30% vom Standard ab!",
        fr => "Les excrétions azotées saisies pour les autres bovins laitières s'écartent de plus de 30 % du
  });
}
return $exc;
```

n_excretion Annual total N excreted by an animalgroup of selected cattle category.

```
Out(n_excretion_animal) * Out(animals);
```

tan_excretion Annual soluble N excreted by an animalgroup of selected cattle category.

```
if ( (not defined In(tan_fraction)) or lc In(tan_fraction) eq 'standard' ) {
  $TE->{"share_Nsol_" . Out(animalcategory)} * Out(n_excretion);
} else {
    my $tan = In(tan_fraction);
    $tan = In(tan_fraction) / 100;
    if ( abs($tan - $TE->{"share_Nsol_" . Out(animalcategory)}) > 0.2) {
      writeLog({
        en => "The TAN fraction of N excretion entered for other cattle differs from the standard by more tha
        de => "Der eingegebene TAN Anteil der N Ausscheidung für übriges Rindvieh weicht um mehr als 20% vom
        fr => "La proportion du TAN des excrétions azotées saisies pour autres bovins s'écartent de plus de 2
      });
    }
    return $tan * Out(n_excretion);
}
```

area_increase Factor on what barn size does increase the regularized minimal, limited to 0.5

```
if ( (Out(animals) < In(dimensioning_barn) ) and (Out(animals) != 0) ) {
  if ( In(dimensioning_barn) >= (Out(animals) * 1.5) ) {
    0.5;
  }
  else {
    In(dimensioning_barn) / Out(animals) - 1;
  }
}
else {
  0.0;
}
```

dimensioning_check Check if number of animals <= number of animal places.

```
if (  In(dimensioning_barn) < Out(animals) ) {
  writeLog({
    en => "The number of available animal places must be equal or higher than the number of animals.",
    de => "Anzahl Tierplätze muss grösser oder gleich der Anzahl der Tiere sein.",
    fr => "Le nombre de places dans l'étable doit être au moins égal au nombre d'animaux."
  });
  return "barn dimensioning too small";
}
else {
  return "barn dimensioning ok";
}
```

Technical Parameters

standard_N_excretion_heifers_1st_yr 25
Annual standard N excretion for a 1 year old heifer, according to Flisch et al. (2009).

standard_N_excretion_heifers_2nd_yr 40
Annual standard N excretion for a 2 year old heifer, according to Flisch et al. (2009).

standard_N_excretion_heifers_3rd_yr 55
Annual standard N excretion for a 3 year old heifer, according to Flisch et al. (2009).

standard_N_excretion_beef_cattle 38
Annual standard N excretion for a beefcattle, according to Flisch et al. (2009).

standard_N_excretion_fattening_calves 18
Annual standard N excretion for a fatteningcalves, according to Flisch et al. (2009).

standard_N_excretion_suckling_cows 85
Annual standard N excretion for a suckling cow, according to Flisch et al. (2009).

standard_N_excretion_suckling_cows_lt600 72
Annual standard N excretion for a suckling cow, according to Flisch et al. (2009).

standard_N_excretion_suckling_cows_gt700 95
Annual standard N excretion for a suckling cow, according to GRUDAF 2017

standard_N_excretion_calves_suckling_cows 22
Annual standard N excretion for calves of suckling cows, according to Flisch et al. (2009).

share_Nsol_heifers_1st_yr 0.55
Nsol content of excreta for 1 year old heifers. Derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

share_Nsol_heifers_2nd_yr 0.55
Nsol content of excreta for 2 years old heifers. Derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

share_Nsol_heifers_3rd_yr 0.55
Nsol content of excreta for 3 years old heifers. Derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

share_Nsol_beef_cattle 0.55
Nsol content of excreta for beefcattle. Derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

share_Nsol_fattening_calves 0.55
Nsol content of excreta for fatteningcalves. Derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

share_Nsol_suckling_cows 0.55
Nsol content of excreta for suckling cows. Derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

share_Nsol_suckling_cows_lt600 0.55
Nsol content of excreta for suckling cows. Derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

share_Nsol_suckling_cows_gt700 0.55
Nsol content of excreta for suckling cows. Derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

share_Nsol_calves_suckling_cows 0.55
Nsol content of excreta for suckling cows. Derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

2.23 Livestock::OtherCattle::Housing

This process calculates the NH3 emission in cattle housing depending on the N excretion and the housing systems. The NH3 emission is assumed to be proportional to the total N excretion of the animals because the contaminated surfaces will primarily drive emission, which will remain active even when animals are on the pasture or exercise yard.

A proportional correction is applied according to the area per animal.

A correction is applied if the part of the day grazing is above a defined grazing hours per days.

2.23.1 Definition of System boundaries for the housing Process:

For housing systems with integrated exercise yards, it is difficult to distinguish between emissions from housing, exercise yard and storage. For these housingtypes the emission may be only validated for the sum of housing, exercise yard and storage emission.

Outputs

n_into_housing Annual N flux into the house.

```
Val(n_excretion, Excretion) -
Val(n_into_grazing, Grazing) -
Val(n_into_yard, Yard);
```

tan_into_housing Annual N flux as TAN into the house.

```
Val(tan_excretion, Excretion) -
Val(tan_into_grazing, Grazing) -
Val(tan_into_yard, Yard);
```

ef_nh3_nhousing NH3 emission factor for other cattle housing systems.

```
my $c_housing = Val(c_grazing, Housing::KGrazing) *
                Val(c_area, Housing::Type) *
                Val(er_housing, Housing::Type) *
                Val(c_housing_floor, Housing::Floor) *
                Val(c_free_factor_housing, Housing::CFreeFactor);
#FIXME: Check: Is it in any way even possible that $c_housing > 1???
$c_housing = 1 unless $c_housing < 1;
return $c_housing;
```

nh3_nhousing Annual NH3 emission from cattle housing systems per animal place.

```
Out(tan_into_housing) * Out(ef_nh3_nhousing);
```

n_outhousing Annual N flux out of housing.

```
Out(n_into_housing) - Out(nh3_nhousing);
```

tan_outhousing Annual N flux as TAN out of housing.

```
Out(tan_into_housing) - Out(nh3_nhousing);
```

n_outhousing_liquid Annual N flux out of housing, slurry or liquid fraction from cattle.

```
Out(n_outhousing) * Val(share_liquid, Housing::Type);
```

tan_outhousing_liquid Annual N flux as TAN out of housing, slurry or liquid fraction from cattle.

```
Out(tan_outhousing) * Val(share_liquid, Housing::Type);
```

n_outhousing_solid Annual N flux out of housing, solid manure fraction of N flux.

```
Out(n_outhousing) - Out(n_outhousing_liquid);
```

tan_outhousing_solid Annual N flux as TAN out of housing, solid manure fraction of N flux.

```
Out(tan_outhousing) - Out(tan_outhousing_liquid);
```

2.24 Livestock::OtherCattle::Housing::Type

This process selects the correction factor for the specific housing types for cattle. Among these correction factors are the emission rate for the housing type, the correction factor for the housing type area, the correction factor for the area per animal, the liquid and solid share for the housing type as well as the factor on what barn size increases the regularized minimal (limited to 0.5).

Inputs

housing_type Type of housing.

Outputs

housing_type Housing type (needed in other modules).

```
In(housing_type);
```

k_area Correction factor for the housing type area.

```
given ( In(housing_type) ) {
  when 'Tied_Housing_Slurry' {
    return Val(k_area, Type::Tied_Housing_Slurry);
  }
  when 'Tied_Housing_Slurry_Plus_Solid_Manure' {
    return Val(k_area, Type::Tied_Housing_Slurry_Plus_Solid_Manure);
  }
  when 'Loose_Housing_Slurry' {
    return Val(k_area, Type::Loose_Housing_Slurry);
  }
  when 'Loose_Housing_Slurry_Plus_Solid_Manure' {
    return Val(k_area, Type::Loose_Housing_Slurry_Plus_Solid_Manure);
  }
  when 'Loose_Housing_Deep_Litter' {
    return Val(k_area, Type::Loose_Housing_Deep_Litter);
  }
}
```

er_housing Emission rate for the housing type.

```
given ( In(housing_type) ) {
  when 'Tied_Housing_Slurry' {
    return Val(er_housing, Type::Tied_Housing_Slurry);
  }
  when 'Tied_Housing_Slurry_Plus_Solid_Manure' {
    return Val(er_housing, Type::Tied_Housing_Slurry_Plus_Solid_Manure);
  }
  when 'Loose_Housing_Slurry' {
    return Val(er_housing, Type::Loose_Housing_Slurry);
  }
  when 'Loose_Housing_Slurry_Plus_Solid_Manure' {
    return Val(er_housing, Type::Loose_Housing_Slurry_Plus_Solid_Manure);
  }
  when 'Loose_Housing_Deep_Litter' {
    return Val(er_housing, Type::Loose_Housing_Deep_Litter);
  }
}
```

share_liquid Liquid share for the housing type.

```
given ( In(housing_type) ) {
  when 'Tied_Housing_Slurry' {
    return Val(share_liquid, Type::Tied_Housing_Slurry);
  }
  when 'Tied_Housing_Slurry_Plus_Solid_Manure' {
    return Val(share_liquid, Type::Tied_Housing_Slurry_Plus_Solid_Manure);
```

```
  }
  when 'Loose_Housing_Slurry' {
    return Val(share_liquid, Type::Loose_Housing_Slurry);
  }
  when 'Loose_Housing_Slurry_Plus_Solid_Manure' {
    return Val(share_liquid, Type::Loose_Housing_Slurry_Plus_Solid_Manure);
  }
  when 'Loose_Housing_Deep_Litter' {
    return Val(share_liquid, Type::Loose_Housing_Deep_Litter);
  }
}
```

c_area Correction factor for area per animal.

```
1 + (Val(area_increase, ..::Excretion) * Out(k_area));
```

2.25 Livestock::OtherCattle::Housing::Type::Tied_Housing_Slurry

This process describes the correction factors for the tied housing slurry system such as the housing specific emission rate, the area per animal correction, the liquid share and solid share.

Outputs

er_housing Emission rate for specific housing type.

```
Tech(er);
```

share_liquid Part of Ntot flowing into liquid storage for selected housing type.

```
Tech(share_liquid);
```

k_area Correction factor for area per animal.

```
Tech(k_area);
```

Technical Parameters

er 0.067
Emission rate for the tide housing slurry system for cattle. According to the consensus obtained in the workshop at ART Tänikon 02/11/07: 4% Ntot, converted using Nsol of 60% and the emission rate of 6.7% based on TAN.

share_liquid 1
For the tide housing slurry system 100% of the manure goes into the liquid fraction of the storage/application.

k_area 0
Additional surfaces are not used.

2.26 Livestock::OtherCattle::Housing::Type::Tied_Housing_Slurry_Plus_Solid_Manure

This process describes the correction factors for the tied housing liquid solid system such as the housing specific emission rate, the area per animal correction, the liquid share and solid share.

Outputs

er_housing Emission rate for specific housing type.

```
Tech(er);
```

share_liquid Part of Ntot flowing into liquid storage for selected housing type.

```
Tech(share_liquid);
```

k_area Correction factor for area per animal.

```
Tech(k_area);
```

Technical Parameters

er 0.067

Emisssion rate for the tide housing liquid solid system for cattle. According to the consensus obtained in the workshop at ART Tänikon 02/11/07: 4% Ntot; converted using Nsol of 60% and the emission rate of 6.7% based on TAN.

share_liquid 0.57

For the tide housing liquid solid system 57% of the manure goes into the liquid fraction of the storage/application.

k_area 0

Additional surfaces are not used.

2.27 Livestock::OtherCattle::Housing::Type::Loose_Housing_Slurry

This process describes the correction factors for the loose housing slurry system such as the housing specific emission rate, the area per animal correction, the liquid share and solid share.

2.27.1 References:

UNECE 2007. Guidance document on control techniques for preventing and abating emissions of ammonia. UNECE executive body for the convention on long-range transboundary air pollution, Working Group on Strategies and Review, EB.AIR/WH.5/2007/13/ 16 July 2007, Genf. 35p.

Outputs

er_housing Emission rate for specific housing type.

```
Tech(er);
```

share_liquid Part of Ntot flowing into liquid storage for selected housing type.

```
Tech(share_liquid);
```

k_area Correction factor for area per animal.

```
Tech(k_area);
```

Technical Parameters

er 0.183
Emission rate for the loose housing slurry system for cattle. According to the consensus obtained in the workshop at ART Tänikon 02/11/07: 11% Ntot; converted using Nsol of 60% and the emission rate of 18.3% based on TAN. Reference value UNECE(2007): 11 kg NH3 = 8% TAN.

share_liquid 1
For the loose housing slurry system 100% of the manure goes into the liquid fraction of the storage/application.

k_area 0.5
According to the consensus obtained in the workshop at ART Tänikon 02/11/07: it is assumed that additional surfaces are entirely used since barriers are hardly fea-sible. The emission is increased by 5% per 10% of additional surfaces up to a maximum of 50% additional surface.

2.28 Livestock::OtherCattle::Housing::Type::Loose_Housing_Slurry_Plus_Solid_Manure

This process describes the correction factors for the loose housing liquid solid system such as the housing specific emission rate, the area per animal correction, the liquid share and solid share.

2.28.1 References:

UNECE 2007. Guidance document on control techniques for preventing and abating emissions of ammonia. UNECE executive body for the convention on long-range transboundary air pollution, Working Group on Strategies and Review, EB.AIR/WH.5/2007/13/ 16 July 2007, Genf. 35p.

Outputs

er_housing Emission rate for specific housing type.

```
Tech(er),
```

share_liquid Part of Ntot flowing into liquid storage for selected housing type.

```
Tech(share_liquid),
```

k_area Correction factor for area per animal.

```
Tech(k_area);
```

Technical Parameters

er 0.183
: Emission rate for the loose housing liquid solid system for cattle. According to the consensus obtained in the workshop at ART Tänikon 02/11/07: 11% Ntot; convered using Nsol of 60% and the emission rate of EF 18.3% based on TAN. Reference value UNECE(2007): 11 kg NH3 = 8% TAN.

share_liquid 0.57
: For the loose housing liquid solid system 57% of the manure goes into the liquid manure storage.

k_area 0.5
: According to the consensus obtained in the workshop at ART Tänikon 02/11/07: it is assumed that additional surfaces are entirely used since barriers are hardly fea-sible. The emission is increased by 5% per 10% of additional surfaces up to a maximum of 50% additional surface.

2.29 Livestock::OtherCattle::Housing::Type::Loose_Housing_Deep_Litter

This process describes the correction factors for the loose housing deep litter system such as the housing specific emission rate, the area per animal correction, the liquid share and solid share.

2.29.1 References:

UNECE 2007. Guidance document on control techniques for preventing and abating emissions of ammonia. UNECE executive body for the convention on long-range transboundary air pollution, Working Group on Strategies and Review, EB.AIR/WH.5/2007/13/ 16 July 2007, Genf. 35p.

Outputs

er_housing Emission rate for specific housing type.

```
Tech(er);
```

share_liquid Part of Ntot flowing into liquid storage for selected housing type.

```
Tech(share_liquid);
```

k_area Correction factor for area per animal.

```
Tech(k_area);
```

Technical Parameters

er 0.183
: Emission rate for the loose housing deep litter system for cattle. According to the consensus obtained in the workshop at ART Tänikon 02/11/07: 11% Ntot; converted using Nsol of 60% and the emission rate of 18.3% based on TAN. Reference value UNECE(2007): 11 kg NH3 = 8% TAN.

share_liquid 0
: For the loose housing deep litter system 100% of the manure does into the solid manure storage/application.

k_area 0.5
: According to the consensus obtained in the workshop at ART Tänikon 02/11/07: it is assumed that additional surfaces are entirely used since barriers are hardly fea-sible. The emission is increased by 5% per 10% of additional surfaces up to a maximum of 50% additional surface.

2.30 Livestock::OtherCattle::Housing::Floor

This submodul calculates the annual NH3 reduction due to a grooved floor in cattle housing systems according to the UNECE guideline 2007.

2.30.1 References

UNECE 2007. Guidance document on control techniques for preventing and abating emissions of ammonia. ECE/EB.AIR/WG.5/2007/13.

Inputs

mitigation_housing_floor Mitigation options for loose housing systems for cattle.

Outputs

c_housing_floor Correction factor for the emission due to the use of a grooved floor in housing systems.

```
return 1 unless defined In(mitigation_housing_floor);
given ( In(mitigation_housing_floor) ) {
  when 'raised_feeding_stands' {
    if ( (Val(housing_type, Type) eq 'Loose_Housing_Slurry') or
        (Val(housing_type, Type) eq 'Loose_Housing_Slurry_Plus_Solid_Manure') ) {
      1 - Tech(red_raised_feeding_stands);
    } else {
      1;
    }
  }
  when 'floor_with_cross_slope_and_collection_gutter' {
    if ( Val(housing_type, Type) eq 'Loose_Housing_Slurry' ) {
      1 - Tech(red_floor_with_cross_slope_and_collection_gutter);
    } else {
      1;
    }
  }
  when 'floor_with_cross_slope_and_collection_gutter_and_raised_feeding_stands' {
    if ( Val(housing_type, Type) eq 'Loose_Housing_Slurry' ) {
      1 - Tech(red_floor_with_cross_slope_and_collection_gutter_and_raised_feeding_stands);
    } else {
      1;
    }
  }
  default {
    # add when "none" & default Warning!
    1;
  }
}
```

Technical Parameters

red_raised_feeding_stands 0.1
Reduction efficiency as compared to cubicle house (UNECE 2007, paragraph 57, table 4).

red_floor_with_cross_slope_and_collection_gutter 0.2
Reduction efficiency as compared to cubicle house (UNECE 2007, paragraph 57, table 4).

red_floor_with_cross_slope_and_collection_gutter_and_raised_feeding_stands 0.3
Reduction efficiency as compared to cubicle house (UNECE 2007, paragraph 57, table 4).

2.31 Livestock::OtherCattle::Housing::CFreeFactor

Inputs

free_correction_factor Factor to define free.

Outputs

c_free_factor_housing Free correction factor for NH3 housing emission.

```
if ( In(free_correction_factor) // 0 != 0 ) {
    writeLog({
      en => "You have entered an additional emission mitigation measure for a housing of the category other c
            . In(free_correction_factor) . "\%!\n",
      de => "Sie haben eine zusätzliche emissionsmindernde Massnahme für einen Stall der Kategorie Übriges Ri
            . In(free_correction_factor) . "\% eingegeben!\n" ,
      fr => "Vous avez introduit une mesure supplémentaire limitant les émissions "
            . "provenant d'une stabulation pour autres bovins de " . In(free_correction_factor) . "\%.\n"
    });
        return 1 - In(free_correction_factor) / 100;
}
else {
  return 1;
}
```

2.32 Livestock::OtherCattle::Housing::KGrazing

This process calculates the correction factor for the non proportional change of the housing emission according to the grazing hours per day. Source is Phillips et al. (1998) and Gilhespy et al. (2006) empirical estimation was done by Thomas Kupper.

Outputs

c_grazing The correction factor for the reduction of the housing emission depending on the number of grazing hours per day and the grazing days per year.

```
my $k_grazing = Tech(k_grazing_a) * exp(Tech(k_grazing_b) * Val(grazing_hours, ..::Outdoor));
# scale with ratio grazing_days per year
($k_grazing - 1) * Val(grazing_days, ..::Outdoor) / 365 + 1;
```

Technical Parameters

k_grazing_a 0.9989
Coefficient a of empirical estimation c = a * exp(b * grazing_hours).

k_grazing_b 0.0403
Coefficient a of empirical estimation c = a * exp(b * grazing_hours).

2.33 Livestock::OtherCattle::Outdoor

Input parameters for exercise yard and grazing.

Inputs

yard_days Access to exercise yards days per year.

exercise_yard Exercise yard: not available, available: roughage is not supplied in the exercise yard, available: roughage is partly supplied in the exercise yard, available: roughage is exclusively supplied in the exercise yard.

floor_properties_exercise_yard Floor properties(solid floor, unpaved floor, perforated floor, paddock or pasture used as exercise yard).

free_correction_factor Factor to define free ?

grazing_days Average grazing days per year.

grazing_hours Average grazing hours per day.

Outputs

yard_days Yard days per year.

```
In(yard_days);
```

exercise_yard Exercise yard type.

```
In(exercise_yard);
```

floor_properties_exercise_yard Exercise yard floor properties.

```
In(floor_properties_exercise_yard);
```

c_free_factor_yard Free reduction of the Emission rate for the Yard.

```
if ( In(free_correction_factor) // 0 != 0 ) {
  writeLog({
    en => "You have entered an additional emission mitigation measure for a dairy cows exercise yard of "
          . In(free_correction_factor) . "\%!\n",
    de => "Sie haben eine zusätzliche emissionsmindernde Massnahme für einen Laufhof der Milchkühe von "
          . In(free_correction_factor) . "\% eingegeben!\n",
    fr => "Vous avez introduit une mesure supplémentaire limitant les émissions provenant d'un parcours "
          . "extérieur pour vâches laitières de " . In(free_correction_factor) . "\% !\n"
  });
  return 1 - In(free_correction_factor) / 100;
} else {
  return 1;
}
```

grazing_hours Grazing hours per day.

```
In(grazing_hours);
```

grazing_days Grazing days per year.

```
In(grazing_days);
```

days_with_grazing_and_yard Number of Days whith access to yard and pasture

```
if( (Out(grazing_days) + Out(yard_days)) > 365 ){
  return Out(grazing_days) + Out(yard_days) - 365;
} else {
  return 0;
}
```

2.34 Livestock::OtherCattle::Yard

Outputs

c_floor_properties_exercise_yard Correction factor for the emission due to the use of the floor properties in housing systems.

```
given ( Val(floor_properties_exercise_yard, Outdoor) ) {
  when 'solid_floor' {
    1 - Tech(red_floor_properties_solid_floor);
  }
  when  'unpaved_floor' {
    1 - Tech(red_floor_properties_unpaved_floor);
  }
  when  'perforated_floor' {
    1 - Tech(red_floor_properties_perforated_floor);
  }
  when  'paddock_or_pasture_used_as_exercise_yard' {
    1 - Tech(red_floor_properties_paddock_or_pasture_used_as_exercise_yard);
  }
  default {
    1;
  }
}
```

share_excretion Share of excretion on the yard according the stay on yard. If the basic feeding is on the yard the share_basicfeeding is assumed. Otherwise the share is selected according to the access.

```
given ( Val(exercise_yard, Outdoor) ) {
  when 'available_roughage_is_not_supplied_in_the_exercise_yard' {
    Tech(share_available_roughage_is_not_supplied_in_the_exercise_yard);
  }
  when 'available_roughage_is_partly_supplied_in_the_exercise_yard' {
    Tech(share_available_roughage_is_partly_supplied_in_the_exercise_yard);
  }
  when 'available_roughage_is_exclusively_supplied_in_the_exercise_yard' {
    Tech(share_available_roughage_is_exclusively_supplied_in_the_exercise_yard);
  }
  when 'not_available' {
    0;
  }
}
```

share_excretion_with_grazing Share of excretion on the yard according the stay on yard with parallel acess to Pasture. If the basic feeding is on the yard the share_basicfeeding is assumed. Otherwise the share is selected according to the access.

```
if( (Val(days_with_grazing_and_yard, Outdoor) > 0) and
    (Out(share_excretion) > Tech(share_available_roughage_is_partly_supplied_in_the_exercise_yard)) ){
  writeLog({
    en => "The category \"roughage is exclusively supplied in the exercise yard\" is not compatible with the
    de => "Verabreichung von Grundfutter ausschliesslich auf dem Laufhof ist nicht möglich mit den eingegeber
    fr => "La distribution de fourrage exclusivement dans le parcours extérieur "
          . "pour les vâches laitières n'est pas possible pendant les jours de pâturage !\n",
  });
  return Tech(share_available_roughage_is_partly_supplied_in_the_exercise_yard);
} else {
  return Out(share_excretion);
}
```

n_into_yard Annual N excretion on yard for a defined animal category.

```
Val(n_excretion, Excretion) *
(
  # yard only (100%)
  Out(share_excretion) *
  (Val(yard_days, Outdoor) - Val(days_with_grazing_and_yard, Outdoor)) / 365 +
```

```
  # yard and grazing (share yard)
  Out(share_excretion_with_grazing) *
  Val(days_with_grazing_and_yard, Outdoor) / 365
);
```

tan_into_yard Annual soluble N excretion on yard for a defined animal category.

```
Val(tan_excretion,Excretion) *
(
  # yard only (100%)
  Out(share_excretion) *
  (Val(yard_days, Outdoor) - Val(days_with_grazing_and_yard, Outdoor)) / 365 +
  # yard and grazing (share yard)
  Out(share_excretion_with_grazing) *
  Val(days_with_grazing_and_yard, Outdoor) / 365
);
```

ef_nh3_nyard Annual NH3 emission from yard.

```
Tech(er_yard) *
Out(c_floor_properties_exercise_yard) *
Val(c_free_factor_yard, Outdoor);
```

nh3_nyard Annual NH3 emission from yard.

```
Out(tan_into_yard) * Out(ef_nh3_nyard);
```

n_outyard_liquid Annual N flux from liquid part out of yard.

```
Out(n_into_yard) - Out(nh3_nyard);
```

tan_outyard_liquid Annual N flux as TAN from liquid part out of yard into storage.

```
Out(tan_into_yard) - Out(nh3_nyard);
```

n_outyard_solid Annual N flux from solid part out of yard.

```
0;
```

tan_outyard_solid Annual N flux as TAN from solid part out of yard into storage.

```
0;
```

Technical Parameters

er_yard 0.7
Emission rate for TAN on yard.

share_available_roughage_is_exclusively_supplied_in_the_exercise_yard 0.6
Share of excretion per day for animals with roughage exclusively on the yard.

share_available_roughage_is_partly_supplied_in_the_exercise_yard 0.2
Share of excretion per day for animals with roughage partly on the yard.

share_available_roughage_is_not_supplied_in_the_exercise_yard 0.1
Share of excretion per day for animals with roughage not supplied in the yard.

red_floor_properties_solid_floor 0.0
Reduction efficiency according to Reidy and Menzi.

red_floor_properties_unpaved_floor 0.5
Reduction efficiency according to Reidy and Menzi.

red_floor_properties_perforated_floor 0.75
Reduction efficiency according to Reidy and Menzi.

red_floor_properties_paddock_or_pasture_used_as_exercise_yard 0.9
Reduction efficiency according to Reidy and Menzi.

2.35 Livestock::OtherCattle::Grazing

This process calculates the annual NH3 emission from grazing cattle based on the total N excreted on the pastures. The N excreted is calculated according to the time the animals spend on the pasture. It assumes that the excretions on the pasture are proportional to the time the animals are grazed.

2.35.1 References:

Bussink DW 1992. Ammonia volatilization from grassland receiving nitrogen fertilizer and rotationally grazed by dairy cattle. Fertilizer Research 33:257-265.

Bussink DW 1994. Relationship between ammonia volatilization and nitrogen fertilizer application rate, intake and excretion of herbage nitrogen by cattle on grazed swards. Fertilizer Research 38:111-121.

Jarvis SC, Hatch DJ, Lockyer DR 1989. Ammonia fluxes from grazed grassland: annual losses from cattle production systems and their relation to nitrogen inputs. Journal of Agricultural Science 113:99-108.

Peterson SO, Sommer SG, Aaes O, Soegaard K 1998. Ammonia losses from urine and dung of grazing cattle: effect of N intake. Atmospheric environment 32:295-300.

Ross CA, Jarvis SC 2001. Measurement of emission and deposition pattern of ammonia from urine in grass swards. Atmospheric environment 35:867-875.

Outputs

n_into_grazing Annual N excretion during grazing for a defined cattle category.

```
Val(n_excretion, Excretion) *
Val(grazing_hours, Outdoor) / 24 *
(
  # grazing only (100%)
  (Val(grazing_days, Outdoor) - Val(days_with_grazing_and_yard, Outdoor)) / 365 +
  # shared grazing(+housing) and yard (100% - share yard)
  # this part is split between grazing and housing by the parts grazing_hours & residual
  (1 - Val(share_excretion_with_grazing, Yard)) *
  Val(days_with_grazing_and_yard, Outdoor) / 365
);
```

tan_into_grazing Annual soluble N (TAN) excretion during grazing for a defined cattle category.

```
Val(tan_excretion, Excretion) *
Val(grazing_hours, Outdoor) / 24 *
(
  # grazing only (100%)
  (Val(grazing_days, Outdoor) - Val(days_with_grazing_and_yard, Outdoor)) / 365 +
  # shared grazing(+housing) and yard (100% - share yard)
  # this part is split between grazing and housing by the parts grazing_hours & residual
  (1 - Val(share_excretion_with_grazing, Yard)) *
  Val(days_with_grazing_and_yard, Outdoor) / 365
);
```

ef_nh3_ngrazing Annual total NH3 emission from all grazing dairy cows.

```
Tech(er_cattle_grazing);
```

nh3_ngrazing Annual NH3 emission from all grazing cattle.

```
Out(tan_into_grazing)  * Out(ef_nh3_ngrazing);
```

n2_ngrazing Annual total N2 emission from all grazing dairy cows.

```
Out(n_into_grazing) * Tech(er_n2_cattle_grazing);
```

no_ngrazing Annual total N2 emission from all grazing dairy cows.

```
Out(n_into_grazing) * Tech(er_no_cattle_grazing);
```

n2o_ngrazing Annual total N2O emission from all grazing dairy cows.

```
Out(n_into_grazing) * Tech(er_n2o_cattle_grazing);
```

n_remain_grazing Annual N input on pastures.

```
Out(n_into_grazing) -
Out(nh3_ngrazing) -
Out(n2_ngrazing) -
Out(no_ngrazing) -
Out(n2o_ngrazing);
```

tan_remain_grazing Annual N input on pastures.

```
Out(tan_into_grazing) -
Out(nh3_ngrazing) -
Out(n2_ngrazing) -
Out(no_ngrazing) -
Out(n2o_ngrazing);
```

Technical Parameters

er_cattle_grazing 0.083
Emission rate for the calculation of the annual NH3 emission during grazing for cattle. 5% Ntot (conversion with a portion of Nsol of 60%: EF 8.3% TAN; value based on Table 1 (Mean emission rate of 3.1% N excreted; range: 1.6-5.7% for grazing cows on a sward fertilized with 250 kg N/y) of Bussink (1992) and Table 3 (Mean emission rate of 3.3% N excreted; range: 0.0-7.4% for grazing cows on a sward fertilized with 250 kg N/y) of Bussink (1994). The corresponding value is rather lower for Switzerland since the level of fertilization is lower resulting in a lower level for crude protein. The N level in the fodder of the sward fertilized with 250 kg N/y (31 g/kg d.m.; Table 4) is comparable to values common for Switzerland (Bussink (1994). The EF chosen includes a safety margin.

er_n2_cattle_grazing 0.0
Emission rate for manure application. Not considerd relevant

er_no_cattle_grazing 0.0055
Emission rate for manure application. Stehfest, Bouwman 2006

er_n2o_cattle_grazing 0.02
Emission rate for manure application. ICCP 2006: v4_11Ch_11; Tab11.1

2.36 Livestock::OtherCattle::NxOx

TODO!

Outputs

er_n2_nsolid Annual N2 emissions from cattles housing, yard and grazing (production).

```
given ( Val(housing_type, Housing::Type) ) {
       return Tech(er_n2_solid_Slurry)                    when 'Tied_Housing_Slurry';
       return Tech(er_n2_solid_Slurry_Plus_Solid_Manure)  when 'Tied_Housing_Slurry_Plus_Solid_Manure';
       return Tech(er_n2_solid_Slurry)                    when 'Loose_Housing_Slurry';
       return Tech(er_n2_solid_Slurry_Plus_Solid_Manure)  when 'Loose_Housing_Slurry_Plus_Solid_Manure';
       return Tech(er_n2_solid_Solid)                     when 'Loose_Housing_Deep_Litter';
       default { return 0; }
 };
```

er_no_nsolid Annual N2 emissions from cattles housing, yard and grazing (production).

```
given ( Val(housing_type, Housing::Type) ) {
       return Tech(er_no_solid_Slurry)                    when 'Tied_Housing_Slurry';
       return Tech(er_no_solid_Slurry_Plus_Solid_Manure)  when 'Tied_Housing_Slurry_Plus_Solid_Manure';
       return Tech(er_no_solid_Slurry)                    when 'Loose_Housing_Slurry';
       return Tech(er_no_solid_Slurry_Plus_Solid_Manure)  when 'Loose_Housing_Slurry_Plus_Solid_Manure';
       return Tech(er_no_solid_Solid)                     when 'Loose_Housing_Deep_Litter';
       default { return 0; }
 };
```

er_n2o_nsolid Annual N2 emissions from cattles housing, yard and grazing (production).

```
given ( Val(housing_type, Housing::Type) ) {
       return Tech(er_n2o_solid_Slurry)                    when 'Tied_Housing_Slurry';
       return Tech(er_n2o_solid_Slurry_Plus_Solid_Manure)  when 'Tied_Housing_Slurry_Plus_Solid_Manure';
       return Tech(er_n2o_solid_Slurry)                    when 'Loose_Housing_Slurry';
       return Tech(er_n2o_solid_Slurry_Plus_Solid_Manure)  when 'Loose_Housing_Slurry_Plus_Solid_Manure';
       return Tech(er_n2o_solid_Solid)                     when 'Loose_Housing_Deep_Litter';
       default { return 0; }
 };
```

er_n2_nliquid Annual N2 emissions from cattles housing, yard and grazing (production).

```
given ( Val(housing_type, Housing::Type) ) {
       return Tech(er_n2_liquid_Slurry)                    when 'Tied_Housing_Slurry';
       return Tech(er_n2_liquid_Slurry_Plus_Solid_Manure)  when 'Tied_Housing_Slurry_Plus_Solid_Manure';
       return Tech(er_n2_liquid_Slurry)                    when 'Loose_Housing_Slurry';
       return Tech(er_n2_liquid_Slurry_Plus_Solid_Manure)  when 'Loose_Housing_Slurry_Plus_Solid_Manure';
       return Tech(er_n2_liquid_Solid)                     when 'Loose_Housing_Deep_Litter';
       default { return 0; }
 };
```

er_no_nliquid Annual N2 emissions from cattles housing, yard and grazing (production).

```
given ( Val(housing_type, Housing::Type) ) {
       return Tech(er_no_liquid_Slurry)                    when 'Tied_Housing_Slurry';
       return Tech(er_no_liquid_Slurry_Plus_Solid_Manure)  when 'Tied_Housing_Slurry_Plus_Solid_Manure';
       return Tech(er_no_liquid_Slurry)                    when 'Loose_Housing_Slurry';
       return Tech(er_no_liquid_Slurry_Plus_Solid_Manure)  when 'Loose_Housing_Slurry_Plus_Solid_Manure';
       return Tech(er_no_liquid_Solid)                     when 'Loose_Housing_Deep_Litter';
       default { return 0; }
 };
```

er_n2o_nliquid Annual N2 emissions from cattles housing, yard and grazing (production).

```
given ( Val(housing_type, Housing::Type) ) {
       return Tech(er_n2o_liquid_Slurry)                    when 'Tied_Housing_Slurry';
       return Tech(er_n2o_liquid_Slurry_Plus_Solid_Manure)  when 'Tied_Housing_Slurry_Plus_Solid_Manure';
       return Tech(er_n2o_liquid_Slurry)                    when 'Loose_Housing_Slurry';
       return Tech(er_n2o_liquid_Slurry_Plus_Solid_Manure)  when 'Loose_Housing_Slurry_Plus_Solid_Manure';
       return Tech(er_n2o_liquid_Solid)                     when 'Loose_Housing_Deep_Litter';
```

```
        default { return 0; }
    };
```

n2_nsolid Annual N2 emission from cattle housing, yard and grazing (production).

```
( Val(n_into_housing, Housing) * (1-Val(share_liquid, Housing::Type) )
) * Out(er_n2_nsolid);
```

no_nsolid Annual NO emission from cattle housing, yard and grazing (production).

```
( Val(n_into_housing, Housing) * (1-Val(share_liquid, Housing::Type) )
) * Out(er_no_nsolid);
```

n2o_nsolid Annual N2o emission from cattle housing, yard and grazing (production).

```
( Val(n_into_housing, Housing) * (1-Val(share_liquid, Housing::Type) )
) * Out(er_n2o_nsolid);
```

n2_nliquid Annual N2 emission from cattle housing, yard and grazing (production).

```
( Val(n_into_housing, Housing) * Val(share_liquid, Housing::Type)  +
  Val(n_into_yard, Yard)
) * Out(er_n2_nliquid);
```

no_nliquid Annual NO emission from cattle housing, yard and grazing (production).

```
( Val(n_into_housing, Housing) * Val(share_liquid, Housing::Type)  +
  Val(n_into_yard, Yard)
) * Out(er_no_nliquid);
```

n2o_nliquid Annual N2o emission from cattle housing, yard and grazing (production).

```
( Val(n_into_housing, Housing) * Val(share_liquid, Housing::Type)  +
  Val(n_into_yard, Yard)
) *  Out(er_n2o_nliquid);
```

Technical Parameters

er_n2_solid_Slurry 0.0
Emission rate for N2 based on Ntot

er_n2_solid_Slurry_Plus_Solid_Manure 0.025
Emission rate for N2 based on Ntot

er_n2_solid_Solid 0.05
Emission rate for N2 based on Ntot

er_n2_liquid_Slurry 0.02
Emission rate for N2 based on Ntot

er_n2_liquid_Slurry_Plus_Solid_Manure 0.02
Emission rate for N2 based on Ntot

er_n2_liquid_Solid 0.05
Emission rate for N2 based on Ntot

er_no_solid_Slurry 0.002
Emission rate for N2 based on Ntot

er_no_solid_Slurry_Plus_Solid_Manure 0.005
Emission rate for N2 based on Ntot

er_no_solid_Solid 0.01
Emission rate for N2 based on Ntot

er_no_liquid_Slurry 0.002
Emission rate for N2 based on Ntot

er_no_liquid_Slurry_Plus_Solid_Manure 0.002
Emission rate for N2 based on Ntot

er_no_liquid_Solid 0.01
Emission rate for N2 based on Ntot

er_n2o_solid_Slurry 0.005
Emission rate for N2 based on Ntot

er_n2o_solid_Slurry_Plus_Solid_Manure 0.005
Emission rate for N2 based on Ntot

er_n2o_solid_Solid 0.01
Emission rate for N2 based on Ntot

er_n2o_liquid_Slurry 0.002
Emission rate for N2 based on Ntot

er_n2o_liquid_Slurry_Plus_Solid_Manure 0.002
Emission rate for N2 based on Ntot

er_n2o_liquid_Solid 0.01
Emission rate for N2 based on Ntot

2.37 Livestock::Pig::Excretion

This process calculates the annual N excretion (total N and Nsol) of different pig categories according to the crude protein and energy content of the feed ration.

TODO (Harald Menzi): Formulation of Beat Reidy maybe mistaken,

2.37.1 References:

BLW, SRVA, LBL 2003. Weisungen zur Beruecksichtigung von Ökofuttern in der Suisse-Bilanz. 2003.

Burgos SA, Robinson PH, Fadel JG, DePeters EJ 2005. Ammonia volatilization potential: Prediction of urinary urea nitrogen output on lactating dairy cows. Agriculture, Ecosystems and Environment 111:261-269.

Peterson SO, Sommer SG, Aaes O, Soegaard K 1998. Ammonia losses from urine and dung of grazing cattle: effect of N intake. Atmospheric environment 32:295-300.

Flisch R, Sinaj S, Charles R, Richner W 2009. Grundlagen für die die Düngung im Acker- und Futterbau. Agrarforschung 16(2).

Inputs

animalcategory Pig category (nursing sows, dry sows, gilts, weaned piglets (up to 25_kg), and boars).

animals Number of animals for the selected type in barn.

dimensioning_barn Number of available animal places.

inp_n_excretion Annual standard N excretion for a pig

tan_fraction TAN fraction of the annual standard N excretion

crude_protein <p>Es sind die Daten des auf dem Betrieb verwendeten Futters einzugeben.</p>

<p>Bei Verwendung von zwei verschiedenen Futtermitteln bei abgesetzten Ferkeln: nach Verzehr gemittelte Gehalt einsetzen.</p>

<p>Standardwerte zur Eingabe, falls die Gehalte des auf dem Betrieb verwendeten Futters nicht bekannt sind:</p>

 Säugende Sauen 180 g RP /kg;

Galtsauen 145 g RP /kg;

Remonten 170 g RP /kg ;

Eber 171 g RP /kg ;

abgesetzte Ferkel 177 g RP /kg

<p>RP-Gehalte von nährstoffreduziertem Futter: </p> Säugende Sauen 155 g RP /kg;

Galtsauen, Remonten und Eber 135 g RP /kg;

abgesetzte Ferkel 165 g RP /kg

energy_content <p>Es sind die Daten des auf dem Betrieb verwendeten Futters einzugeben.</p>

<p>Bei Verwendung von zwei verschiedenen Futtermitteln bei abgesetzten Ferkeln: nach Verzehr gemittelten Gehalt einsetzen.</p>

Standardwerte zur Eingabe, falls die Gehalte des auf dem Betrieb verwendeten Futters nicht bekannt sind:

 Säugende Sauen: 13.7 MJ VES /kg Galtsauen: 12.1 MJ VES /kg Remonten: 14.0 MJ VES /kg Eber: 12.9 MJ VES /kg; abgesetzte Ferkel: 13.7 MJ VES /kg

Outputs

animals Number of pigs of a specific category.

```
In(animals);
```

animalcategory Animal category

```
In(animalcategory);
```

n_excretion_animal Annual total N excreted per animal.

```
my $minimal = $TE->{'minimal_N_excretion_' . Out(animalcategory)};
my $stdN = $TE->{'standard_N_excretion_' . Out(animalcategory)};
if ( (not defined In(inp_n_excretion)) or lc In(inp_n_excretion) eq 'standard' ) {
  my $Nexcr =  $stdN*
            (1 -
              ($TE->{'standard_crude_protein_' . Out(animalcategory)} -
                In(crude_protein) * $TE->{'standard_energy_content_' . Out(animalcategory)} / In(energy_conte
              ) *
            $TE->{'cfeed_' . Out(animalcategory)});
  if( $Nexcr < $minimal ) {
    writeLog({
      en => "The entries for the contents of energy and crude protein of the ration result in a N excretion b
            . "The excretion was set to " . $minimal ." kg N per animal!",
      de => "Der gewählte Energie- und Rohproteingehalt der Ration bewirken eine N Ausscheidung unterhalb des
            . "Die Ausscheidung wurde auf ". $minimal ."  kg N pro Tier gesetzt!",
      fr => "La teneur de la ration en énergie et en matière azotée engendrent une excrétion de N inférieure
            . "Les excrétions azotées ont été fixées à". $minimal ."  kg N par animal!"
    });
    return $minimal;
  } else {
    return $Nexcr;
  }
} else {
  if( In(inp_n_excretion) < $minimal ) {
    writeLog({
      en => "The entry for N excretion is below the minimum for pigs!",
      de => "Der gewählte N Ausscheidung liegt unterhalb des Minimums für Schweine!",
      fr => "Les excrétions azotées sont inférieures au minimum pour les porcs!"
    });
  }
  if ( In(inp_n_excretion) < 0.7 * $stdN or
       In(inp_n_excretion) > 1.3 * $stdN ) {
    writeLog({
      en => "The N excretion entered for pigs differs from the standard by more than 30%!",
      de => "Die eingegebene N-Ausscheidung für Zuchtschweine weicht um mehr als 30% vom Standard ab.",
      fr => "Les excrétions azotées saisies pour les porcs s'écartent de plus de 30% du standard!"
    });
  }
  return In(inp_n_excretion);
}
```

n_excretion Annual total N excreted by a specified number of animals.

```
Out(n_excretion_animal) * Out(animals);
```

tan_excretion Annual soluble N excreted by a specified number fo pigs.

```
if ( (not defined In(tan_fraction)) or lc In(tan_fraction) eq 'standard' ) {
  Tech(share_Nsol) * Out(n_excretion);
```

```
} else {
    my $tan = In(tan_fraction);
    $tan = In(tan_fraction) / 100;
    if ( abs($tan - Tech(share_Nsol)) > 0.2) {
      writeLog({
        en => "The TAN fraction of N excretion entered for pigs differs from the standard by more than 20%!",
        de => "Der eingegebene TAN Anteil der N Ausscheidung für Schweine weicht um mehr als 20% vom Standard
        fr => "La proportion du TAN des excrétions azotées saisies pour les porcs s'écartent de plus de 20 %
      });
    }
    return $tan * Out(n_excretion);
}
```

area_increase Factor on what barn size does increase the regularized minimal, limited to 0.5

```
if ( (Out(animals) < In(dimensioning_barn) ) and (Out(animals) != 0) ) {
  if ( In(dimensioning_barn) >= (Out(animals) * 1.5) ) {
    0.5;
  }
  else {
    In(dimensioning_barn) / Out(animals) - 1;
  }
}
else {
  0.0;
}
```

dimensioning_check Check if number of animals <= number of animal places.

```
if ( In(dimensioning_barn) < Out(animals) ) {
  writeLog({
    en => "The number of available animal places must be equal or higher than the number of animals.",
    de => "Anzahl Tierplätze muss grösser oder gleich der Anzahl der Tiere sein.",
    fr => "Le nombre de places dans l'étable doit être au moins égal au nombre d'animaux."
  });
  return "barn dimensioning too small";
}
else {
  return "barn dimensioning ok";
}
```

Technical Parameters

standard_N_excretion_nursing_sows 49
Annual standard N excretion for animal category (nursing sows) according to Flisch et al. (2009).

standard_N_excretion_dry_sows 25
Annual standard N excretion for animal category (dry sows) according to Flisch et al. (2009).

standard_N_excretion_gilts 13
Annual standard N excretion for animal category (gilts) according to Flisch et al. (2009).

standard_N_excretion_weaned_piglets_up_to_25kg 3.9
Annual standard N excretion for animal category (piglets) according to Flisch et al. (2009).

standard_N_excretion_boars 18
Annual standard N excretion for animal category (boars) according to Flisch et al. (2009).

standard_crude_protein_nursing_sows 180
Standard crude protein content of a feed ration for nursing sows (BLW, SRVA, LBL 2003). Agridea, BLW (2010).

standard_crude_protein_dry_sows 145
Standard crude protein content of a feed ration for dry sows(BLW, SRVA, LBL 2003). Agridea, BLW (2010).

standard_crude_protein_gilts 170
: Standard crude protein content of a feed ration for gilts (BLW, SRVA, LBL 2003). Agridea, BLW (2010).

standard_crude_protein_weaned_piglets_up_to_25kg 177
: Standard crude protein content of a feed ration for piglets (BLW, SRVA, LBL 2003). Agridea, BLW (2010).

standard_crude_protein_boars 171
: Standard crude protein content of a feed ration for boars (BLW, SRVA, LBL 2003). Agridea, BLW (2010).

standard_energy_content_nursing_sows 13.7
: Standard energy content of a feed ration for nursing sows (BLW, SRVA, LBL 2003). Agridea, BLW (2010).

standard_energy_content_dry_sows 12.1
: Standard energy content of a feed ration for dry sows (BLW, SRVA, LBL 2003). Agridea, BLW (2010).

standard_energy_content_gilts 14
: Standard energy content of a feed ration for

standard_energy_content_weaned_piglets_up_to_25kg 13.7
: Standard energy content of a feed ration for

standard_energy_content_boars 12.9
: Standard energy content of a feed ration for

cfeed_nursing_sows 0.008
: Correction factor for feed with reduced crude protein content

cfeed_dry_sows 0.006
: Correction factor for feed with reduced crude protein content

cfeed_gilts 0.009
: Correction factor for feed with reduced crude protein content

cfeed_weaned_piglets_up_to_25kg 0.012
: Correction factor for feed with reduced crude protein content

cfeed_boars 0.008
: Correction factor for feed with reduced crude protein content

minimal_N_excretion_nursing_sows 37.2
: Annual minimal N excretion for pig category (nursing sows) according to

minimal_N_excretion_dry_sows 21.6
: Annual minimal N excretion for pig category (dry sows) according to Flisch et al. (2009). Agridea, BLW (2010).

minimal_N_excretion_gilts 9.5
: Annual minimal N excretion for pig category (gilts) according to Flisch et al. (2009). Agridea, BLW (2010).

minimal_N_excretion_weaned_piglets_up_to_25kg 2.9
: Annual minimal N excretion for pig category (piglets) according to Flisch et al. (2009). Agridea, BLW (2010).

minimal_N_excretion_boars 13.5
: Annual minimal N excretion for pig category (boars) according to Flisch et al. (2009). Agridea, BLW (2010).

share_Nsol 0.7
Nsol content of excreta from pigs. Derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

2.38 Livestock::Pig::Housing

This process calculates the NH3 emission in pig housing depending on the N excretion and the housing systems. The NH3 emission is assumed to be proportional to the total N excretion of the animals because the contaminated surfaces will primarily drive emissions, which will remain active even when animals are on the pasture or exercise yard.

A proportional correction is applied according to the area per animal.

A correction is applied if the part of the day grazing is above a defined grazing hours per days.

2.38.1 Definition of System boundaries for the housing Process:

For housing systems with integrated exercise yards, it is difficult to distinguish between emissions from housing, exercise yard and storage. For these housingtypes the emission may be only validated for the sum of housing, exercise yard and storage emission.

Outputs

n_into_housing Annual N flux into the house.

```
Val(n_excretion, Excretion) - Val(n_into_grazing, Grazing);
```

tan_into_housing Annual N flux as TAN into the house.

```
Val(tan_excretion, Excretion) - Val(tan_into_grazing, Grazing);
```

ef_housing_indoor_before_air_scrubber NH3 emission factor for indoor part before air scrubber removal of other pig housing systems.

```
my $ef = Val(er_housing, Housing::Type) *
          Val(c_free_factor_housing, Housing::CFreeFactor) *
          Val(c_area, Housing::Type) *
          (1 - Val(red_housing_floor, Housing::MitigationOptions)) *
          (1 - Val(red_housing_air, Housing::MitigationOptions));
#FIXME: Add message if $ef > 1?
$ef = 1 unless $ef < 1;
return $ef;
```

ef_housing_indoor NH3 emission factor for indoor part of other pig housing systems.

```
Out(ef_housing_indoor_before_air_scrubber) *
(1 - Val(red_air_scrubber, Housing::AirScrubber));
```

ef_housing_grazing NH3 emission factor for grazing part of other pig housing systems.

```
my $ef = Val(er_housing, Housing::Type) *
          Val(c_free_factor_housing, Housing::CFreeFactor) *
          Val(c_area, Housing::Type);
#FIXME: Add message if $ef > 1?
$ef = 1 unless $ef < 1;
return $ef;
```

ef_nh3_nhousing NH3 emission factor for other pig housing systems.

```
Val(share_indoor, Housing::Type) * Out(ef_housing_indoor) +
# grazing part
(1 - Val(share_indoor, Housing::Type)) * Out(ef_housing_grazing);
```

nh3_nhousing Annual NH3 emission from pig housing systems.

```
Out(tan_into_housing) * Out(ef_nh3_nhousing);
```

tan_air_scrubber Annual N of NH3 emission remaining in air scrubber from pig housing systems.

```
if ( Val(air_scrubber, Housing::AirScrubber) eq 'biotrickling' ) {
  # 100% of n in biotrickling filter vanishes
  Val(share_indoor, Housing::Type) *
  # reduction efficiency of air scrubber
  Val(red_air_scrubber, Housing::AirScrubber) *
  # multiplied with indoor loss before air scrubber removal
  Val(tan_excretion,Excretion) * Out(ef_housing_indoor_before_air_scrubber);
} else {
  # n in acid scrubber adds 100% to flux into storage
  0;
}
```

n_outhousing Annual N flux out of the housing excluding N remained in biotrickling filter.

```
Out(n_into_housing) - Out(nh3_nhousing) - Out(tan_air_scrubber);
```

tan_outhousing Annual N flux as TAN out of the housing excluding N remained in biotrickling filter. (without remains from acid filter)

```
Out(tan_into_housing) - Out(nh3_nhousing) - Out(tan_air_scrubber);
```

n_outhousing_liquid Annual N flux out of housing, slurry or liquid fraction from pigs.

```
Out(n_outhousing) * Val(share_liquid, Housing::Type);
```

tan_outhousing_liquid Annual N flux as TAN out of housing, slurry or liquid fraction from pigs.

```
Out(tan_outhousing) * Val(share_liquid, Housing::Type);
```

n_outhousing_solid Annual N flux out of housing, manure fraction of N flux from pigs.

```
Out(n_outhousing) - Out(n_outhousing_liquid);
```

tan_outhousing_solid Annual N flux as TAN out of housing, manure fraction of N flux from pigs.

```
Out(tan_outhousing) - Out(tan_outhousing_liquid);
```

2.39 Livestock::Pig::Housing::Type

This process selects the correction factor for the specific housing types for pigs. Among these correction factors are the emission rate for the housing type, the correction factor for the housing type area, the correction factor for the area per animal, the liquid and solid share for the housing type as well as the factor on what barn size increases the regularized minimal (limited to 0.5).

Inputs

housing_type Type of housing.

Outputs

housing_type Housing type (needed in other modules).

```
In(housing_type);
```

er_housing Emission rate for the housing type.

```
given ( Out(housing_type) ) {
  when 'Outdoor' {
   Val(er_housing, Type::Outdoor);
  }
  when 'Slurry_Conventional' {
   Val(er_housing, Type::Slurry_Conventional);
  }
  when 'Slurry_Label' {
   Val(er_housing, Type::Slurry_Label);
  }
  when 'Slurry_Label_Open' {
   Val(er_housing, Type::Slurry_Label_Open);
  }
  when 'Deep_Litter' {
   Val(er_housing, Type::Deep_Litter);
  }
}
```

share_liquid Liquid share for the housing type.

```
given ( Out(housing_type) ) {
  when 'Outdoor' {
   Val(share_liquid, Type::Outdoor);
  }
  when 'Slurry_Conventional' {
   Val(share_liquid, Type::Slurry_Conventional);
  }
  when 'Slurry_Label' {
   Val(share_liquid, Type::Slurry_Label);
  }
  when 'Slurry_Label_Open' {
   Val(share_liquid, Type::Slurry_Label_Open);
  }
  when 'Deep_Litter' {
   Val(share_liquid, Type::Deep_Litter);
  }
}
```

share_indoor Factor for considering grazing part.

```
if ( Out(housing_type) eq 'Slurry_Label' or Out(housing_type) eq 'Slurry_Label_Open' ) {
   return 0.5;
}
else {
   return 1;
}
```

c_area Correction factor for area per animal.

```
1 + (Val(area_increase, ..::Excretion) * Tech(k_area));
```

Technical Parameters

k_area 0.5
Increasing factor for larger loose housing barns, +10 to +5

2.40 Livestock::Pig::Housing::Type::Slurry_Conventional

This process describes the correction factors for the conventional slurry pig housing system such as the housing specific emission rate, the liquid share and solid share.

Outputs

er_housing Emission rate for specific housing type.

```
Tech(er);
```

share_liquid Liquid part of Ntot for selected housing type.

```
Tech(share_liquid);
```

Technical Parameters

er 0.243
Emission rate for the conventional slurry pig housing system. According to the consensus obtained in the workshop at ART Tänikon 02/11/07: 17 % Ntot; converted using Nsol of 70% and the emission rate of 24.3 % based on TAN.

share_liquid 1
For the conventional slurry pig housing system 100% of the manure goes into the liquid fraction for storage/application.

2.41 Livestock::Pig::Housing::Type::Slurry_Label

This process describes the correction factors for the label slurry pig housing system such as the housing specific emission rate, the liquid share and solid share.

Outputs

er_housing Emission rate for specific housing type.

```
Tech(er);
```

share_liquid Liquid part of Ntot for selected housing type.

```
Tech(share_liquid);
```

Technical Parameters

er 0.486
Emission rate for the label slurry pig housing system. According to the consensus obtained in the workshop at ART Tänikon 02/11/07: 34 % Ntot; converted using Nsol of 70% and the emission rate of 48.6 % based on TAN.

share_liquid 1
For the label slurry pig housing system 100% of the manure goes into the liquid fraction for storage/application.

2.42 Livestock::Pig::Housing::Type::Slurry_Label_Open

This process describes the correction factors for the label slurry open pig housing system such as the housing specific emission rate, the liquid share and solid share.

Outputs

er_housing Emission rate for specific housing type.

```
Tech(er);
```

share_liquid Liquid part of Ntot for selected housing type.

```
Tech(share_liquid);
```

Technical Parameters

er 0.34

Emission rate for the label slurry open front pig housing system: 70% of the emission rate for the label slurry pig housing system (14.07.2010). According to the consensus obtained in the workshop at ART Tänikon 02/11/07: 34 % Ntot; converted using Nsol of 70% and the emissions rate of 48.6 % based on TAN.

share_liquid 1

For the label slurry open front pig housing system 100% of the manure goes into the liquid fraction for storage/application.

2.43 Livestock::Pig::Housing::Type::Deep_Litter

This process describes the correction factors for the label deep litter pig housing system such as the housing specific emission rate, the liquid share and solid share.

Outputs

er_housing Emission rate for specific housing type.

```
Tech(er);
```

share_liquid Liquid part of Ntot for selected housing type.

```
Tech(share_liquid);
```

Technical Parameters

er 0.486
Emission rate for the label deep litter fattening pig housing system. According to the Review of EAGER on Solid Manure. Webb et al. (2012). ”er” is based on TAN Flux into housing.

share_liquid 0
For the label deep litter pig housing system 100% of the manure goes into solid manure storage/application.

2.44 Livestock::Pig::Housing::Type::Outdoor

This process describes the correction factors for grazing pigs such as the housing specific emission rate, the liquid share and solid share. Outdoor pigs do not have any housing emissions, as everything is excreted on pasture.

TODO (Note): justification

Outputs

er_housing Emission rate for specific housing type.

```
Tech(er);
```

share_liquid Liquid part of Ntot for selected housing type.

```
Tech(share_liquid);
```

Technical Parameters

er 0
Emission rate for grazing pigs (equal to zero because all emissions are listed under grazing).

share_liquid 0
For the grazing pigs 0% of the manure goes into the liquid fraction for storage/application.

2.45 Livestock::Pig::Housing::AirScrubber

This submodul calculates the annual NH3 reduction due to an exhaust air scrubber in housing systems according to the UNECE guideline 2007.

2.45.1 References:

UNECE 2007. Guidance document on control techniques for preventing and abating emissions of ammonia. ECE/EB.AIR/WG.5/2007/13.

Inputs

air_scrubber Exhaust air scrubber: none, acid, biotrickling_filter.

Outputs

air_scrubber air exhaust scrubber in housing systems.

```
In(air_scrubber);
```

red_air_scrubber Reduction factor for the emission due to the use of an air exhaust scrubber in housing systems.

```
given ( In(air_scrubber) ) {
  when 'acid' {
    return Tech(red_acid_air_scrubber);
  }
  when 'biotrickling' {
    return Tech(red_biotrickling_filter_air_scrubber);
  }
  when 'none' {
    return 0;
  }
  default {
    writeLog({
      en => "Invalid 'exhaust air scrubber' entered!",
      de => "Ungültige 'Abluftreinigung' eingegeben!",
      fr => "Entrée non valable pour ‘Traitement des effluents gazeux'!"
    });
    return 0;
  }
}
```

Technical Parameters

red_acid_air_scrubber 0.9
Reduction efficiency as compared to group-housed on fully and partly slatted floors (UNECE 2007, paragraph 71, table 5).

red_biotrickling_filter_air_scrubber 0.7
Reduction efficiency as compared to group-housed on fully and partly slatted floors (UNECE 2007, paragraph 71, table 5).

2.46 Livestock::Pig::Housing::MitigationOptions

This submodul calculates the annual NH3 reduction due to an exhaust air scrubber in housing systems according to the UNECE guideline 2007.

2.46.1 References:

UNECE 2007. Guidance document on control techniques for preventing and abating emissions of ammonia. ECE/EB.AIR/WG.5/2007/13.

Inputs

mitigation_housing_floor No selection available at the moment.

mitigation_housing_air Mitigation option air supply for pigs

Outputs

red_housing_floor Reduction factor for the emission due to UNECE housing systems tasks for fully and partly slatted floors.

```
given ( In(mitigation_housing_floor) ) {
  when "none" {
    0;
  }
  default {
    # Warning falls not defined mitigation_housing_floor_LU
    0;
  }
}
```

red_housing_air Reduction factor for the emission due to the use of housing system adaptations.

```
if (In(mitigation_housing_air)  eq 'low_impuls_air_supply'){
    return( Tech(red_low_impuls_air_supply));
}
else {
    return 0;
}
```

Technical Parameters

red_low_impuls_air_supply 0.2
Reduction efficiency for LU Model Version (Workshop SHL Zollikofen, 08.02.2010).

2.47 Livestock::Pig::Housing::CFreeFactor

This process selects the correction factor for the specific housing types for pigs. Among these correction factors are the emission rate for the housing type, the correction factor for the housing type area, the correction factor for the area per animal, the liquid and solid share for the housing type as well as the factor on what barn size increases the regularized minimal (limited to 0.5).

Inputs

free_correction_factor Factor to define free.

Outputs

c_free_factor_housing Free correction factor for NH3 housing emission.

```
if ( In(free_correction_factor) // 0 != 0 ) {
  writeLog({
    en => "You have entered an additional emission mitigation measure for a housing of the category pigs of "
          . In(free_correction_factor) . "\%.\n",
    de => "Sie haben eine zusätzliche emissionsmindernde Massnahme für einen  Stall der Kategorie Schweine vo
          . In(free_correction_factor) . "\% eingegeben.\n",
    fr => "Vous avez introduit une mesure supplémentaire limitant les émissions dans les "
          . "stabulations pour porcs de " . In(free_correction_factor) . "\%.\n"
  });
  return 1 - In(free_correction_factor) / 100;
}
else {
  return 1;
}
```

2.48 Livestock::Pig::Grazing

This process calculates the annual NH3 emission from grazing pigs based on the N excreted on the pastures. The N excreted is calculated according to the time the animals spend on the pasture. It assumes that the excretions on the pasture are proportional to the time the animals are grazed.

2.48.1 References:

Bussink DW 1992. Ammonia volatilization from grassland receiving nitrogen fertilizer and rotationally grazed by dairy cattle. Fertilizer Research 33:257-265.

Bussink DW 1994. Relationship between ammonia volatilization and nitrogen fertilizer application rate, intake and excretion of herbage nitrogen by cattle on grazed swards. Fertilizer Research 38:111-121.

Flisch R, Sinaj S, Charles R, Richner W 2009. Grundlagen für die die Düngung im Acker- und Futterbau. Agrarforschung 16(2).

Jarvis SC, Hatch DJ, Lockyer DR 1989. Ammonia fluxes from grazed grassland: annual losses from cattle production systems and their relation to nitrogen inputs. Journal of Agricultural Science 113:99-108.

Peterson SO, Sommer SG, Aaes O, Soegaard K 1998. Ammonia losses from urine and dung of grazing cattle: effect of N intake. Atmospheric environment 32:295-300.

Ross CA, Jarvis SC 2001. Measurement of emission and deposition pattern of ammonia from urine in grass swards. Atmospheric environment 35:867-875.

Sommer SG, Sogaard HT, Moller HB, Morsing S 2001. Ammonia volatilization from sows on grassland. Atmospheric environment 35:2023-2032.

Outputs

n_into_grazing Annual N excretion during grazing for pigs.

```
if(Val(housing_type, Housing::Type) eq 'Outdoor'){
  Val(n_excretion, Excretion);
}else {
  0;
}
```

tan_into_grazing Annual soluble N (TAN) excretion during grazing for pigs.

```
if(Val(housing_type, Housing::Type) eq 'Outdoor'){
  Val(tan_excretion, Excretion);
}else {
  0;
}
```

ef_nh3_ngrazing Annual total NH3 emission from all grazing dairy cows.

```
if(Val(housing_type, Housing::Type) eq 'Outdoor'){
  Tech(er_pig_grazing);
}else {
  0;
}
```

nh3_ngrazing Annual NH3 emission from all pigs from grazing.

```
Out(tan_into_grazing) * Out(ef_nh3_ngrazing);
```

n2_ngrazing Annual total N2 emission from all grazing dairy cows.

```
Out(n_into_grazing) * Tech(er_n2_pig_grazing);
```

no_ngrazing Annual total N2 emission from all grazing dairy cows.

```
Out(n_into_grazing) * Tech(er_no_pig_grazing);
```

n2o_ngrazing Annual total N2O emission from all grazing dairy cows.

```
Out(n_into_grazing) * Tech(er_n2o_pig_grazing);
```

n_remain_grazing Annual N input on pastures.

```
Out(n_into_grazing) -
Out(nh3_ngrazing) -
Out(n2_ngrazing) -
Out(no_ngrazing) -
Out(n2o_ngrazing);
```

tan_remain_grazing Annual N input on pastures.

```
Out(tan_into_grazing) -
Out(nh3_ngrazing) -
Out(n2_ngrazing) -
Out(no_ngrazing) -
Out(n2o_ngrazing);
```

Technical Parameters

er_pig_grazing 0.2
Emission rate for the calculation of the annual NH3 emission during grazing for pigs. Sommer et al. (2001) give a yearly volatilization loss from one sow with piglets of 4.8 kg N resulting in a loss of 20% TAN assuming an N excretion/sow/y of 35 kg N (Flisch et al. (2009)).

er_n2_pig_grazing 0.0
Emission rate for manure application. Not considerd relevant

er_no_pig_grazing 0.0055
Emission rate for manure application. Stehfest, Bouwman 2006

er_n2o_pig_grazing 0.02
Emission rate for manure application. ICCP 2006: v4_11Ch_11; Tab11.1

2.49 Livestock::Pig::NxOx

TODO!

Outputs

er_n2_nsolid Annual N2 emissions from pigs housing, yard and grazing (production).

```
given ( Val(housing_type, Housing::Type) ) {
      return Tech(er_n2_solid_Slurry)        when 'Slurry_Conventional';
      return Tech(er_n2_solid_Slurry)        when 'Slurry_Label';
      return Tech(er_n2_solid_Solid)         when 'Deep_Litter';
      return Tech(er_n2_solid_Solid)         when 'Outdoor';
      default { return 0; }
 };
```

er_no_nsolid Annual N2 emissions from pigs housing, yard and grazing (production).

```
given ( Val(housing_type, Housing::Type) ) {
      return Tech(er_no_solid_Slurry)        when 'Slurry_Conventional';
      return Tech(er_no_solid_Slurry)        when 'Slurry_Label';
      return Tech(er_no_solid_Solid)         when 'Deep_Litter';
      return Tech(er_no_solid_Solid)         when 'Outdoor';
      default { return 0; }
 };
```

er_n2o_nsolid Annual N2 emissions from pigs housing, yard and grazing (production).

```
given ( Val(housing_type, Housing::Type) ) {
      return Tech(er_n2o_solid_Slurry)        when 'Slurry_Conventional';
      return Tech(er_n2o_solid_Slurry)        when 'Slurry_Label';
      return Tech(er_n2o_solid_Solid)         when 'Deep_Litter';
      return Tech(er_n2o_solid_Solid)         when 'Outdoor';
      default { return 0; }
 };
```

er_n2_nliquid Annual N2 emissions from pigs housing, yard and grazing (production).

```
given ( Val(housing_type, Housing::Type) ) {
      return Tech(er_n2_liquid_Slurry)        when 'Slurry_Conventional';
      return Tech(er_n2_liquid_Slurry)        when 'Slurry_Label';
      return Tech(er_n2_liquid_Solid)         when 'Deep_Litter';
      return Tech(er_n2_liquid_Solid)         when 'Outdoor';
      default { return 0; }
 };
```

er_no_nliquid Annual N2 emissions from pigs housing, yard and grazing (production).

```
given ( Val(housing_type, Housing::Type) ) {
      return Tech(er_no_liquid_Slurry)        when 'Slurry_Conventional';
      return Tech(er_no_liquid_Slurry)        when 'Slurry_Label';
      return Tech(er_no_liquid_Solid)         when 'Deep_Litter';
      return Tech(er_no_liquid_Solid)         when 'Outdoor';
      default { return 0; }
 };
```

er_n2o_nliquid Annual N2 emissions from pigs housing, yard and grazing (production).

```
given ( Val(housing_type, Housing::Type) ) {
      return Tech(er_n2o_liquid_Slurry)        when 'Slurry_Conventional';
      return Tech(er_n2o_liquid_Slurry)        when 'Slurry_Label';
      return Tech(er_n2o_liquid_Solid)         when 'Deep_Litter';
      return Tech(er_n2o_liquid_Solid)         when 'Outdoor';
      default { return 0; }
 };
```

n2_nsolid Annual N2 emissions from pigs housing, yard and grazing (production).

```
( Val(n_into_housing, Housing) * (1-Val(share_liquid, Housing::Type) )
) * Out(er_n2_nsolid);
```

no_nsolid Annual NO emissions from pigs housing, yard and grazing (production).

```
( Val(n_into_housing, Housing) * (1-Val(share_liquid, Housing::Type) )
) * Out(er_no_nsolid);
```

n2o_nsolid Annual N2O emissions from pigs housing, yard and grazing (production).

```
( Val(n_into_housing, Housing) * (1-Val(share_liquid, Housing::Type) )
) * Out(er_n2o_nsolid);
```

n2_nliquid Annual N2 emissions from pigs housing, yard and grazing (production).

```
( Val(n_into_housing, Housing) * Val(share_liquid, Housing::Type)
) * Out(er_n2_nliquid);
```

no_nliquid Annual NO emissions from pigs housing, yard and grazing (production).

```
( Val(n_into_housing, Housing) * Val(share_liquid, Housing::Type)
) * Out(er_no_nliquid);
```

n2o_nliquid Annual N2O emissions from pigs housing, yard and grazing (production).

```
( Val(n_into_housing, Housing) * Val(share_liquid, Housing::Type)
) *  Out(er_n2o_nliquid);
```

Technical Parameters

er_n2_solid_Slurry 0.02
Emission rate for N2 based on Ntot

er_n2_solid_Solid 0.05
Emission rate for N2 based on Ntot

er_n2_liquid_Slurry 0.02
Emission rate for N2 based on Ntot

er_n2_liquid_Solid 0.05
Emission rate for N2 based on Ntot

er_no_solid_Slurry 0.002
Emission rate for N2 based on Ntot

er_no_solid_Solid 0.01
Emission rate for N2 based on Ntot

er_no_liquid_Slurry 0.002
Emission rate for N2 based on Ntot

er_no_liquid_Solid 0.01
Emission rate for N2 based on Ntot

er_n2o_solid_Slurry 0.002
Emission rate for N2 based on Ntot

er_n2o_solid_Solid 0.01
Emission rate for N2 based on Ntot

er_n2o_liquid_Slurry 0.002
Emission rate for N2 based on Ntot

er_n2o_liquid_Solid 0.01
Emission rate for N2 based on Ntot

2.50 Livestock::FatteningPigs::Excretion

This process calculates the annual N excretion (total N and Nsol) of fattening pigs according to the crude protein and energy content of the feed ration.

TODO (Harald Menzi): Formulation of Beat Reidy maybe mistaken,

2.50.1 References:

BLW, SRVA, LBL 2003. Weisungen zur Beruecksichtigung von Ökofuttern in der Suisse-Bilanz. 2003.

Burgos SA, Robinson PH, Fadel JG, DePeters EJ 2005. Ammonia volatilization potential: Prediction of urinary urea nitrogen output on lactating dairy cows. Agriculture, Ecosystems and Environment 111:261-269.

Petersen SO, Sommer SG, Aaes O, Soegaard K 1998. Ammonia losses from urine and dung of grazing cattle: effect of N intake. Atmospheric environment 32:295-300.

Flisch R, Sinaj S, Charles R, Richner W 2009. Grundlagen für die die Düngung im Acker- und Futterbau. Agrarforschung 16(2).

Inputs

animalcategory Animal category

animals Number of fattening pigs for the selected type in barn.

dimensioning_barn Number of available animal places.

inp_n_excretion Annual standard N excretion for a fattening pig

tan_fraction TAN fraction of the annual standard N excretion

feeding_phase_1_crude_protein Bei Durchmast (von 25 kg bis zur Schlachtung gleiches Futter eingesetzt): den RP Gehalt des verwendeten Durchmastfutters eingeben und unten bei Mastphase 2 und 3 den gleichen Wert wie für Mastphase 1 eingeben.

Bei Phasenfütterung: RP-Gehalt des auf dem Betrieb verwendeten Futters von Mastphase 1 eingeben.

<p>Standardwerte zur Eingabe, falls die Gehalte des auf dem Betrieb verwendeten Futters nicht bekannt sind:</p>

 Bei Durchmast: 170 g RP /kg

Mastphase 1 bei 2-Phasenfütterung und bei 3-Phasenfütterung: 175 g RP /kg

<p>Bei Verwendung von NPr Futter:</p> Bei Durchmast: 155 g RP /kg

Mastphase 1 bei 2-Phasenfütterung und bei 3-Phasenfütterung: 160 g RP /kg

feeding_phase_2_crude_protein Bei Durchmast: den gleichen Wert wie für Mastphase 1 eingeben

Bei 2-Phasenfütterung: den RP Gehalt des auf dem Betrieb verwendeten Futters von Mastphase 2 eingeben und unten bei Mastphase 3 den gleichen Wert wie für Mastphase 2 eingeben

Bei 3-Phasenfütterung: den RP Gehalt des auf dem Betrieb verwendeten Futters von Mastphase 2 eingeben

<p>Vorschlag für Standardwerte:</p>

 Mastphase 2 bei 2-Phasenfütterung und bei 3-Phasenfütterung: 160 g RP /kg

<p>Bei Verwendung von NPr Futter:</p>

 Mastphase 2 bei 2-Phasenfütterung und bei 3-Phasenfütterung: 150 g RP /kg

feeding_phase_3_crude_protein Bei Durchmast und 2-Phasenfütterung: den gleichen Wert wie für Mastphase 1 eingeben

Bei 3-Phasenfütterung: den RP Gehalt des auf dem Betrieb verwendeten Futters von Mastphase 3 eingeben

<p>Standardwerte zur Eingabe, falls die Gehalte des auf dem Betrieb verwendeten Futters nicht bekannt sind:</p>

 Mastphase 3 bei 3-Phasenfütterung: 150 g RP /kg

<p>Bei Verwendung von NPr Futter:</p>

 Mastphase 3 bei 3-Phasenfütterung: 140 g RP /kg

energy_content Energy content of feed ration.

Outputs

animals Number of fattening pigs of a specific category.

```
In(animals);
```

animalcategory Animal category

```
In(animalcategory);
```

crude_protein Crude protein content of feed ration - for 1-, 2- or 3-phase-feeding.

```
if ( In(feeding_phase_3_crude_protein) == 0 or
     In(feeding_phase_2_crude_protein) == In(feeding_phase_3_crude_protein) ) {
  if ( In(feeding_phase_2_crude_protein) == 0 ) {
    In(feeding_phase_1_crude_protein);
  }
  else {
    In(feeding_phase_1_crude_protein) * Tech(phase_1_2_duration) +
    In(feeding_phase_2_crude_protein) * Tech(phase_2_2_duration);
  }
}
else {
  In(feeding_phase_1_crude_protein) * Tech(phase_1_3_duration) +
  In(feeding_phase_2_crude_protein) * Tech(phase_2_3_duration) +
  In(feeding_phase_3_crude_protein) * Tech(phase_3_3_duration)
}
```

n_excretion_animal Annual standard N excretion for fattening pigs according to Walther et al. (2001).

```
if ( (not defined In(inp_n_excretion)) or lc In(inp_n_excretion) eq 'standard' ) {
  my $exc = Tech(standard_N_excretion_fattening_pigs) *
            (1 - (
              Tech(standard_crude_protein_fattening_pigs) -
              (Out(crude_protein) * Tech(standard_energy_content_fattening_pigs) / In(energy_content))
            ) *
            Tech(cfeed_fattening_pigs));
  if ( $exc < Tech(minimal_N_excretion_fattening_pigs) ) {
    writeLog({
      en => "The entry for the N excretion is below the minimum for fattening pigs. \n"
            . "The excretion was set to " . Tech(minimal_N_excretion_fattening_pigs) . " kg N per animal!",
      de => "Die gewählte N Ausscheidung liegt unterhalb des Minimums für Mastschweine! \n"
```

```
          . "Die Ausscheidung wurde auf ". Tech(minimal_N_excretion_fattening_pigs) ." kg N pro Tier gesetz
      fr => "La teneur de la ration en énergie et en matière azotée engendrent une "
          ."excrétion  de N inférieure au minimum prévu pour les porcs à l'engrais. "
          ."L'excrétion a été fixée à ". Tech(minimal_N_excretion_fattening_pigs) ."kg N par animal. \n"
    });
    return Tech(minimal_N_excretion_fattening_pigs);
  } else {
    return $exc;
  }
} else {
  if ( In(inp_n_excretion) < Tech(minimal_N_excretion_fattening_pigs) ) {
    writeLog({
      en => "The entry for the N excretion is below the minimum for fattening pigs!",
      de => "Die gewählte N Ausscheidung liegt unterhalb des Minimums für Mastschweine!",
      fr => "Les excrétions azotées sont inférieures au minimum pour les porcs à l'engrais!"
    });
  }
  if ( (In(inp_n_excretion) < 0.7 * Tech(standard_N_excretion_fattening_pigs)) or (In(inp_n_excretion) > 1.3
    writeLog({
        en => "The N excretion entered for fattening pigs differs from the standard by more than 30%!",
        de => "Die eingegebene N-Ausscheidung für Mastschweine weicht um mehr als 30% vom Standard ab!",
        fr => "Les excrétions azotées saisies les porcs à l'engrais s'écartent de plus de 30 % du standard!",
    });
  }
  return In(inp_n_excretion);
}
```

n_excretion Annual total N excreted by a specified number of fattening pigs.

```
Out(n_excretion_animal) * Out(animals);
```

tan_excretion Annual soluble N excreted by a specified number of fattening pigs.

```
if ( (not defined In(tan_fraction)) or lc In(tan_fraction) eq 'standard' ) {
  Tech(share_Nsol) * Out(n_excretion);
} else {
    my $tan = In(tan_fraction);
    $tan = In(tan_fraction) / 100;
    if ( abs($tan - Tech(share_Nsol)) > 0.2) {
      writeLog({
        en => "The TAN fraction of N excretion entered for fattening pigs differs from the standard by more t
        de => "Der eingegebene TAN Anteil der N Ausscheidung für Mastschweine weicht um mehr als 20% vom Stan
        fr => "La proportion du TAN des excrétions azotées saisies pour les porcs à l'engrais s'écartent de p
      });
    }
    return $tan * Out(n_excretion);
}
```

area_increase Factor on what barn size does increase the regularized minimal, limited to 0.5

```
if ( (Out(animals) < In(dimensioning_barn) ) and (Out(animals) != 0) ) {
  if ( In(dimensioning_barn) >= (Out(animals) * 1.5) ) {
    0.5;
  }
  else {
    In(dimensioning_barn) / Out(animals) - 1;
  }
}
else {
  0.0;
}
```

dimensioning_check Check if number of animals <= number of animal places.

```
if ( In(dimensioning_barn) < Out(animals) ) {
  writeLog({
    en => "The number of available animal places must be equal or higher than the number of animals.",
    de => "Anzahl Tierplätze muss grösser oder gleich der Anzahl der Tiere sein.",
    fr => "Le nombre de places dans l'étable doit être au moins égal au nombre d'animaux."
```

```
    });
    return "barn dimensioning too small";
  }
  else {
    return "barn dimensioning ok";
  }
```

Technical Parameters

standard_N_excretion_fattening_pigs 13.0
: Annual standard N excretion for fattening pigs according to Flisch et al. (2009).

standard_energy_content_fattening_pigs 14.0
: Standard energy content of a feed ration for fattening pigs (BLW, SRVA, LBL 2003). Agridea, BLW (2010).

standard_crude_protein_fattening_pigs 170.0
: Standard crude protein content of a feed ration for fattening pigs (BLW, SRVA, LBL 2003). Agridea, BLW (2010).

cfeed_fattening_pigs 0.009
: Correction factor for feed with reduced crude protein content for fatteing pigs (BLW, SRVA, LBL 2003). A diffrence from 10 g CP /kg leads to 8 0/0 . Agridea, BLW (2010).

minimal_N_excretion_fattening_pigs 9.5
: Annual minimal N excretion for fattening pigs according to Flisch et al. (2009). Agridea, BLW (2010).

share_Nsol 0.7
: Nsol content of excreta from fattening pigs. Derived from e.g. Petersen et al. (1998) or Burgos et al. (2005).

phase_1_3_duration 0.151
: Feeding phase 1 of a 3-phase-feeding duration as part of the year.

phase_2_3_duration 0.321
: Feeding phase 2 of a 3-phase-feeding duration as part of the year.

phase_3_3_duration 0.528
: feeding phase 3 of a 3-phase-feeding duration as part of the year.

phase_1_2_duration 0.359
: Feeding phase 1 of a 2-phase-feeding duration as part of the year.

phase_2_2_duration 0.641
: Feeding phase 2 of a 2-phase-feeding duration as part of the year.

2.51 Livestock::FatteningPigs::Housing

This process calculates the NH3 emission in fattening pig housing depending on the N excretion and the housing systems. The NH3 emission is assumed to be proportional to the total N excretion of the animals because the contaminated surfaces will primarily drive emissions, which will remain active even when animals are on the pasture or exercise yard.

A proportional correction is applied according to the area per animal.

A correction is applied if the part of the day grazing is above a defined grazing hours per days.

2.51.1 Definition of System boundaries for the housing Process:

For housing systems with integrated exercise yards, it is difficult to distinguish between emissions from housing, exercise yard and storage. For these housingtypes the emission may be only validated for the sum of housing, exercise yard and storage emission.

Outputs

n_into_housing Annual N flux into the house.

```
Val(n_excretion, Excretion) - Val(n_into_grazing, Grazing);
```

tan_into_housing Annual N flux as TAN into the house.

```
Val(tan_excretion, Excretion) - Val(tan_into_grazing, Grazing);
```

ef_housing_indoor_before_air_scrubber NH3 emission factor for indoor part before air scrubber removal of other pig housing systems.

```
my $ef = Val(er_housing, Housing::Type) *
          Val(c_area, Housing::Type) *
          Val(c_free_factor_housing, Housing::CFreeFactor) *
          (1 - Val(red_housing_floor, Housing::MitigationOptions)) *
          (1 - Val(red_housing_air, Housing::MitigationOptions));
#FIXME: Add message if $ef > 1?
$ef = 1 unless $ef < 1;
return $ef;
```

ef_housing_indoor NH3 emission factor for indoor part of fattening pig housing systems.

```
Out(ef_housing_indoor_before_air_scrubber) *
(1 - Val(red_air_scrubber, Housing::AirScrubber));
```

ef_housing_grazing NH3 emission factor for grazing part of fattening pig housing systems.

```
my $ef = Val(er_housing, Housing::Type) *
          Val(c_free_factor_housing, Housing::CFreeFactor) *
          Val(c_area, Housing::Type);
#FIXME: Add message if $ef > 1?
$ef = 1 unless $ef < 1;
return $ef;
```

ef_nh3_nhousing NH3 emission factor for fattening pig housing systems.

```
Val(share_indoor, Housing::Type) * Out(ef_housing_indoor) +
# grazing part
(1 - Val(share_indoor, Housing::Type)) * Out(ef_housing_grazing);
```

nh3_nhousing Annual NH3 emission from fattening pig housing systems.

```
Out(tan_into_housing) * Out(ef_nh3_nhousing);
```

tan_air_scrubber Annual N of NH3 emission remaining in air scrubber from pig housing systems.

```
if ( Val(air_scrubber, Housing::AirScrubber) eq 'biotrickling' ) {
  # 100% of n in biotrickling filter vanishes
  Val(share_indoor, Housing::Type) *
  # reduction efficiency of air scrubber
  Val(red_air_scrubber, Housing::AirScrubber) *
  # multiplied with indoor loss before air scrubber removal
  Val(tan_excretion,Excretion) * Out(ef_housing_indoor_before_air_scrubber);
} else {
  # n in acid scrubber adds 100% to flux into storage
  0;
}
```

n_outhousing Annual N flux out of the housing excluding N remained in biotrickling filter, (without remains in acid filter).

```
Out(n_into_housing) - Out(nh3_nhousing) - Out(tan_air_scrubber);
```

tan_outhousing Annual N flux as TAN out of the housing excluding N remained in biotrickling filter.

```
Out(tan_into_housing) - Out(nh3_nhousing) - Out(tan_air_scrubber);
```

n_outhousing_liquid Annual N flux out of housing, slurry or liquid fraction from fattening pigs.

```
Out(n_outhousing) * Val(share_liquid,Housing::Type);
```

tan_outhousing_liquid Annual N flux as TAN out of housing, slurry or liquid fraction from fattening pigs.

```
Out(tan_outhousing) * Val(share_liquid,Housing::Type);
```

n_outhousing_solid Annual N flux out of housing, manure fraction of N flux from fattening pigs.

```
Out(n_outhousing) - Out(n_outhousing_liquid);
```

tan_outhousing_solid Annual N flux as TAN out of housing, manure fraction of N flux from fattening pigs.

```
Out(tan_outhousing) - Out(tan_outhousing_liquid);
```

2.52 Livestock::FatteningPigs::Housing::Type

This process selects the correction factor for the specific housing types for fattening pigs. Among these correction factors are the emission rate for the housing type, the correction factor for the housing type area, the correction factor for the area per animal, the liquid and solid share for the housing type as well as the factor on what barn size increases the regularized minimal (limited to 0.5).

Inputs

housing_type Type of housing.

Outputs

housing_type Housing type (needed in other modules).

```
In(housing_type);
```

er_housing Emission rate for the housing type.

```
given ( Out(housing_type) ) {
  when 'Outdoor' {
         Val(er_housing, Type::Outdoor);
  }
  when 'Slurry_Conventional' {
         Val(er_housing, Type::Slurry_Conventional);
  }
  when 'Slurry_Label' {
         Val(er_housing, Type::Slurry_Label);
  }
  when 'Slurry_Label_Open' {
         Val(er_housing, Type::Slurry_Label_Open);
  }
  when 'Deep_Litter' {
         Val(er_housing, Type::Deep_Litter);
  }
}
```

share_liquid Liquid share for the housing type.

```
given ( Out(housing_type) ) {
  when 'Outdoor' {
   Val(share_liquid, Type::Outdoor);
  }
  when 'Slurry_Conventional' {
   Val(share_liquid, Type::Slurry_Conventional);
  }
  when 'Slurry_Label' {
   Val(share_liquid, Type::Slurry_Label);
  }
  when 'Slurry_Label_Open' {
   Val(share_liquid, Type::Slurry_Label_Open);
  }
  when 'Deep_Litter' {
   Val(share_liquid, Type::Deep_Litter);
  }
}
```

share_indoor Factor for considering indoor mitigation efficiencies.

```
if ( Out(housing_type) eq 'Slurry_Label' or Out(housing_type) eq 'Slurry_Label_Open' ) {
  return 0.5;
}
else {
  return 1;
}
```

c_area Correction factor for area per animal.

```
1 + (Val(area_increase, ..::Excretion) * Tech(k_area));
```

Technical Parameters

k_area 0.5
Increasing factor for larger loose housing barns, +10 to +5

2.53 Livestock::FatteningPigs::Housing::Type::Slurry_Conventional

This process describes the correction factors for the conventional slurry fattening pig housing system such as the housing specific emission rate, the liquid share and solid share.

Outputs

er_housing Emission rate for specific housing type.

```
Tech(er);
```

share_liquid Liquid part of Ntot for selected housing type.

```
Tech(share_liquid);
```

Technical Parameters

er 0.243
Emission rate for the conventional slurry fattening pig housing system. According to the consensus obtained in the workshop at ART Tänikon 02/11/07: 17 % Ntot; converted using Nsol of 70% and the emission rate of 24.3 % based on TAN.

share_liquid 1
For the conventional slurry fattening pig housing system 100% of the manure goes into the liquid fraction for storage/application.

2.54 Livestock::FatteningPigs::Housing::Type::Slurry_Label

This process describes the correction factors for the label slurry fattening pig housing system such as the housing specific emission rate, the liquid share and solid share.

Outputs

er_housing Emission rate for specific housing type.

```
Tech(er);
```

share_liquid Liquid part of Ntot for selected housing type.

```
Tech(share_liquid);
```

Technical Parameters

er 0.486

Emission rate for the label slurry fattening pig housing system. According to the consensus obtained in the workshop at ART Tänikon 02/11/07: 34 % Ntot; converted using Nsol of 70% and the emission rate of 48.6 % based on TAN.

share_liquid 1

For the label slurry fattening pig housing system 100% of the manure goes into the liquid fraction for storage/application.

2.55 Livestock::FatteningPigs::Housing::Type::Slurry_Label_Open

This process describes the correction factors for the label slurry open fattening pig housing system such as the housing specific emission rate, the liquid share and solid share.

Outputs

er_housing Emission rate for specific housing type.

```
Tech(er);
```

share_liquid Liquid part of Ntot for selected housing type.

```
Tech(share_liquid);
```

Technical Parameters

er 0.34

Emission rate for the label slurry open front fattening pig housing system: 70% of the emission rate for the label slurry fattening pig housing system (14.07.2010). According to the consensus obtained in the workshop at ART Tänikon 02/11/07: 34 % Ntot; converted using Nsol of 70% and the emission rate of 48.6 % based on TAN.

share_liquid 1

For the label slurry open front fattening pig housing system 100% of the manure goes into the liquid fraction for storage/application.

2.56 Livestock::FatteningPigs::Housing::Type::Deep_Litter

This process describes the correction factors for the label deep litter fattening pig housing system such as the housing specific emission rate, the liquid share and solid share.

Outputs

er_housing Emission rate for specific housing type.

```
Tech(er);
```

share_liquid Liquid part of Ntot for selected housing type.

```
Tech(share_liquid);
```

Technical Parameters

er 0.486
Emission rate for the label deep litter fattening pig housing system. According to the Review of EAGER on Solid Manure. Webb et al. (2012). ”er” is based on TAN Flux into housing.

share_liquid 0
For the label deep litter fattening pig housing system 100% of the manure goes into solid manure storage/application.

2.57 Livestock::FatteningPigs::Housing::Type::Outdoor

This process describes the correction factors for grazing fattening pigs such as the housing specific emission rate, the liquid share and solid share. Outdoor fattening pigs do not have any housing emissions, as everything is excreted on pasture.

TODO (Note): justification

Outputs

er_housing Emission rate for specific housing type.

```
Tech(er);
```

share_liquid Liquid part of Ntot for selected housing type.

```
Tech(share_liquid);
```

Technical Parameters

er 0
Emission rate for grazing fattening pigs (equal to zero because all emissions are listed under grazing).

share_liquid 0
For the grazing fattening pigs 0% of the manure goes into the liquid fraction for storage/application.

2.58 Livestock::FatteningPigs::Housing::AirScrubber

This submodul calculates the annual NH3 reduction due to an exhaust air scrubber in fattening pig housing systems according to the UNECE guideline 2007.

2.58.1 References:

UNECE 2007. Guidance document on control techniques for preventing and abating emissions of ammonia. ECE/EB.AIR/WG.5/2007/13.

Inputs

air_scrubber Air exhaust scrubber (none, acid, biotrickling_filter).

Outputs

air_scrubber air exhaust scrubber in housing systems.

```
In(air_scrubber);
```

red_air_scrubber Reduction factor for the emission due to the use of an air exhaust scrubber in housing systems.

```
given ( In(air_scrubber) ) {
  when 'acid' {
    return Tech(red_acid_air_scrubber);
  }
  when 'biotrickling' {
    return Tech(red_biotrickling_filter_air_scrubber);
  }
  when 'none' {
    return 0;
  }
  default {
    writeLog({
      en => "Invalid 'exhaust air scrubber' entered!",
      de => "Ungültige 'Abluftreinigung' eingegeben!",
      fr => "Entrée non valable pour ‘Traitement des effluents gazeux'!"
    });
    return 0;
  }
}
```

Technical Parameters

red_acid_air_scrubber 0.9
Reduction efficiency as compared to group-housed on fully and partly slatted floors (UNECE 2007, paragraph 71, table 5).

red_biotrickling_filter_air_scrubber 0.7
Reduction efficiency as compared to group-housed on fully and partly slatted floors (UNECE 2007, paragraph 71, table 5).

2.59 Livestock::FatteningPigs::Housing::MitigationOptions

This submodul calculates the annual NH3 reduction due to an air exhaust scrubber in fattening pig housing systems according to the UNECE guideline 2007.

2.59.1 References:

UNECE 2007. Guidance document on control techniques for preventing and abating emissions of ammonia. ECE/EB.AIR/WG.5/2007/13.

Inputs

mitigation_housing_floor No selection available at the moment.

mitigation_housing_air Mitigation option air supply for pigs

Outputs

red_housing_floor Reduction factor for the emission due to UNECE housing systems tasks for fully and partly slatted floors.

```
given ( In(mitigation_housing_floor) ) {
  when "none" {
    0;
  }
  default {
    # TODO: Warning not defined mitigation_housing_floor! (Same with red_housing_air below)
    0;
  }
}
```

red_housing_air Reduction factor for the emission due to the use of housing system adaptations.

```
if (In(mitigation_housing_air)  eq 'low_impuls_air_supply'){
    return( Tech(red_low_impuls_air_supply));
}
else {
    return 0;
}
```

Technical Parameters

red_low_impuls_air_supply 0.2
Reduction efficiency for LU Model Version (Workshop SHL Zollikofen, 08.02.2010).

2.60 Livestock::FatteningPigs::Housing::CFreeFactor

This process selects the correction factor for the specific housing types for fattening pigs. Among these correction factors are the emission rate for the housing type, the correction factor for the housing type area, the correction factor for the area per animal, the liquid and solid share for the housing type as well as the factor on what barn size increases the regularized minimal (limited to 0.5).

Inputs

free_correction_factor Factor to define free.

Outputs

c_free_factor_housing Free correction factor for NH3 housing emission.

```
if ( In(free_correction_factor) // 0 != 0 ) {
  writeLog({
    en => "You have entered an additional emission mitigation measure for a fattening pigs housing of "
          . In(free_correction_factor) . "\%.\n",
    de => "Sie haben eine zusätzliche emissionsmindernde Massnahme für einen Stall der Mastschweine von "
          . In(free_correction_factor) . "\% eingegeben.\n",
    fr => "Vous avez introduit une mesure supplémentaire limitant les émissions dans les "
          . "stabulations pour porcs à l'engrais de " .  In(free_correction_factor) . "\%.\n"
  });
  return 1 - In(free_correction_factor)/100;
}
else {
  return 1;
}
```

2.61 Livestock::FatteningPigs::Grazing

This process calculates the annual NH3 emission from grazing fattening pigs based on the N excreted on the pastures. The N excreted is calculated according to the time the animals spend on the pasture. It assumes that the excretions on the pasture are proportional to the time the animals are grazed.

2.61.1 References:

Bussink DW 1992. Ammonia volatilization from grassland receiving nitrogen fertilizer and rotationally grazed by dairy cattle. Fertilizer Research 33:257-265.

Bussink DW 1994. Relationship between ammonia volatilization and nitrogen fertilizer application rate, intake and excretion of herbage nitrogen by cattle on grazed swards. Fertilizer Research 38:111-121.

Flisch R, Sinaj S, Charles R, Richner W 2009. Grundlagen für die die Düngung im Acker- und Futterbau. Agrarforschung 16(2).

Jarvis SC, Hatch DJ, Lockyer DR 1989. Ammonia fluxes from grazed grassland: annual losses from cattle production systems and their relation to nitrogen inputs. Journal of Agricultural Science 113:99-108.

Peterson SO, Sommer SG, Aaes O, Soegaard K 1998. Ammonia losses from urine and dung of grazing cattle: effect of N intake. Atmospheric environment 32:295-300.

Ross CA, Jarvis SC 2001. Measurement of emission and deposition pattern of ammonia from urine in grass swards. Atmospheric environment 35:867-875.

Outputs

n_into_grazing Annual N excretion during grazing for fattening pigs.

```
if(Val(housing_type, Housing::Type) eq 'Outdoor'){
  return Val(n_excretion, Excretion);
}else {
  return 0;
}
```

tan_into_grazing Annual soluble N (TAN) excretion during grazing for fattening pigs.

```
if(Val(housing_type, Housing::Type) eq 'Outdoor'){
  return Val(tan_excretion, Excretion);
}else {
  return 0;
}
```

ef_nh3_ngrazing Annual total NH3 emission from all grazing dairy cows.

```
if(Val(housing_type, Housing::Type) eq 'Outdoor'){
  Tech(er_fattening_pig_grazing);
}else {
  0;
}
```

nh3_ngrazing Annual NH3 emission from all fattening pigs from grazing.

```
Out(tan_into_grazing) * Out(ef_nh3_ngrazing);
```

n2_ngrazing Annual total N2 emission from all grazing dairy cows.

```
Out(n_into_grazing) * Tech(er_n2_fattening_pig_grazing);
```

no_ngrazing Annual total N2 emission from all grazing dairy cows.

```
Out(n_into_grazing) * Tech(er_no_fattening_pig_grazing);
```

n2o_ngrazing Annual total N2O emission from all grazing dairy cows.

```
Out(n_into_grazing) * Tech(er_n2o_fattening_pig_grazing);
```

n_remain_grazing Annual N input on pastures.

```
Out(n_into_grazing) -
Out(nh3_ngrazing) -
Out(n2_ngrazing) -
Out(no_ngrazing) -
Out(n2o_ngrazing);
```

tan_remain_grazing Annual N input on pastures.

```
Out(tan_into_grazing) -
Out(nh3_ngrazing) -
Out(n2_ngrazing) -
Out(no_ngrazing) -
Out(n2o_ngrazing);
```

Technical Parameters

er_fattening_pig_grazing 0.2
Emission rate for the calculation of the annual NH3 emission during grazing for fattening pigs. Sommer et al. (2001) give a yearly volatilization loss from one sow with piglets of 4.8 kg N resulting in a loss of 20% TAN assuming an N excretion/sow/y of 35 kg N (Flisch et al. (2009)).

er_n2_fattening_pig_grazing 0.0
Emission rate for manure application. Not considerd relevant

er_no_fattening_pig_grazing 0.0055
Emission rate for manure application. Stehfest, Bouwman 2006

er_n2o_fattening_pig_grazing 0.02
Emission rate for manure application. ICCP 2006: v4_11Ch_11; Tab11.1

2.62 Livestock::FatteningPigs::NxOx

TODO!

Outputs

er_n2_nsolid Annual N2 emissions from fattening pigs housing, yard and grazing (production).

```
given ( Val(housing_type, Housing::Type) ) {
  return Tech(er_n2_solid_Slurry) when 'Slurry_Conventional';
  return Tech(er_n2_solid_Slurry) when 'Slurry_Label';
  return Tech(er_n2_solid_Solid)  when 'Deep_Litter';
  return Tech(er_n2_solid_Solid)  when 'Outdoor';
  default { return 0; }
};
```

er_no_nsolid Annual N2 emissions from fattening pigs housing, yard and grazing (production).

```
given ( Val(housing_type, Housing::Type) ) {
  return Tech(er_no_solid_Slurry) when 'Slurry_Conventional';
  return Tech(er_no_solid_Slurry) when 'Slurry_Label';
  return Tech(er_no_solid_Solid)  when 'Deep_Litter';
  return Tech(er_no_solid_Solid)  when 'Outdoor';
  default { return 0; }
};
```

er_n2o_nsolid Annual N2 emissions from fattening pigs housing, yard and grazing (production).

```
given ( Val(housing_type, Housing::Type) ) {
  return Tech(er_n2o_solid_Slurry)  when 'Slurry_Conventional';
  return Tech(er_n2o_solid_Slurry)  when 'Slurry_Label';
  return Tech(er_n2o_solid_Solid)   when 'Deep_Litter';
  return Tech(er_n2o_solid_Solid)   when 'Outdoor';
  default { return 0; }
};
```

er_n2_nliquid Annual N2 emissions from fattening pigs housing, yard and grazing (production).

```
given ( Val(housing_type, Housing::Type) ) {
  return Tech(er_n2_liquid_Slurry)  when 'Slurry_Conventional';
  return Tech(er_n2_liquid_Slurry)  when 'Slurry_Label';
  return Tech(er_n2_liquid_Solid)   when 'Deep_Litter';
  return Tech(er_n2_liquid_Solid)   when 'Outdoor';
  default { return 0; }
};
```

er_no_nliquid Annual N2 emissions from fattening pigs housing, yard and grazing (production).

```
given ( Val(housing_type, Housing::Type) ) {
  return Tech(er_no_liquid_Slurry)  when 'Slurry_Conventional';
  return Tech(er_no_liquid_Slurry)  when 'Slurry_Label';
  return Tech(er_no_liquid_Solid)   when 'Deep_Litter';
  return Tech(er_no_liquid_Solid)   when 'Outdoor';
  default { return 0; }
};
```

er_n2o_nliquid Annual N2 emissions from fattening pigs housing, yard and grazing (production).

```
given ( Val(housing_type, Housing::Type) ) {
  return Tech(er_n2o_liquid_Slurry) when 'Slurry_Conventional';
  return Tech(er_n2o_liquid_Slurry) when 'Slurry_Label';
  return Tech(er_n2o_liquid_Solid)  when 'Deep_Litter';
  return Tech(er_n2o_liquid_Solid)  when 'Outdoor';
  default { return 0; }
};
```

n2_nsolid Annual N2 emissions from fattening pigs housing, yard and grazing (production).

```
(
 Val(n_into_housing, Housing) *
 (1 - Val(share_liquid, Housing::Type))
) * Out(er_n2_nsolid);
```

no_nsolid Annual NO emissions from fattening pigs housing, yard and grazing (production).

```
(
 Val(n_into_housing, Housing) *
 (1 - Val(share_liquid, Housing::Type))
) * Out(er_no_nsolid);
```

n2o_nsolid Annual N2O emissions from fattening pigs housing, yard and grazing (production).

```
(
 Val(n_into_housing, Housing) *
 (1 - Val(share_liquid, Housing::Type))
) * Out(er_n2o_nsolid);
```

n2_nliquid Annual N2 emissions from fattening pigs housing, yard and grazing (production).

```
( Val(n_into_housing, Housing) * Val(share_liquid, Housing::Type)
) * Out(er_n2_nliquid);
```

no_nliquid Annual NO emissions from fattening pigs housing, yard and grazing (production).

```
( Val(n_into_housing, Housing) * Val(share_liquid, Housing::Type)
) * Out(er_no_nliquid);
```

n2o_nliquid Annual N2O emissions from fattening pigs housing, yard and grazing (production).

```
( Val(n_into_housing, Housing) * Val(share_liquid, Housing::Type)
) *  Out(er_n2o_nliquid);
```

Technical Parameters

er_n2_solid_Slurry 0.02
Emission rate for N2 based on Ntot

er_n2_solid_Solid 0.05
Emission rate for N2 based on Ntot

er_n2_liquid_Slurry 0.02
Emission rate for N2 based on Ntot

er_n2_liquid_Solid 0.05
Emission rate for N2 based on Ntot

er_no_solid_Slurry 0.002
Emission rate for N2 based on Ntot

er_no_solid_Solid 0.01
Emission rate for N2 based on Ntot

er_no_liquid_Slurry 0.002
Emission rate for N2 based on Ntot

er_no_liquid_Solid 0.01
Emission rate for N2 based on Ntot

er_n2o_solid_Slurry 0.002
Emission rate for N2 based on Ntot

er_n2o_solid_Solid 0.01
Emission rate for N2 based on Ntot

er_n2o_liquid_Slurry 0.002
Emission rate for N2 based on Ntot

er_n2o_liquid_Solid 0.01
Emission rate for N2 based on Ntot

2.63 Livestock::Poultry::Excretion

This process calculates the annual N excretion of the different poultry categories. The standard N excretion was taken from the official Swiss fertilizer guidelines. The Nsol content of the excreta is based on e.g. Peterson et al. (1998) or Burgos et al. (2005). These values were compiled on the basis of official feeding recommendations (Flisch et al. (2009)) by H. Menzi.

2.63.1 References:

Burgos SA, Robinson PH, Fadel JG, DePeters EJ 2005. Ammonia volatilization potential: Prediction of urinary urea nitrogen output on lactating dairy cows. Agriculture, Ecosystems and Environment 111:261-269.

Peterson SO, Sommer SG, Aaes O, Soegaard K 1998. Ammonia losses from urine and dung of grazing cattle: effect of N intake. Atmospheric environment 32:295-300.

Flisch R, Sinaj S, Charles R, Richner W 2009. Grundlagen für die die Düngung im Acker- und Futterbau. Agrarforschung 16(2).

Inputs

animalcategory Poultry category (layers, growers, broilers, turkeys, and other poultry).

animals Number of poultry animals for the selected type in barn.

dimensioning_barn Number of available animal places.

inp_n_excretion Annual standard N excretion for poultry

tan_fraction TAN fraction of the annual standard N excretion

Outputs

animals Number of poultry animals for the selected type in barn.

```
In(animals);
```

animalcategory Poultry category (layers, growers, broilers, turkeys, and other poultry).

```
In(animalcategory);
```

n_excretion_animal Annual standard N excretion for specified poultry category according to Flisch et al. (2009).

```
my $cat = Out(animalcategory);
my $key = 'standard_N_excretion_' . $cat;
my $exc = $TE->{$key};
$exc = In(inp_n_excretion) unless ( (not defined In(inp_n_excretion)) or lc In(inp_n_excretion) eq 'standard'
if (($exc < 0.7 * $TE->{$key}) or ($exc > 1.3 * $TE->{$key})) {
    writeLog({
        en => "The N excretion entered for poultry differs from the standard by more than 30%!",
        de => "Die eingegebene N-Ausscheidung für Geflügel weicht um mehr als 30% vom Standard ab!",
        fr => "Les excrétions azotées saisies pour les volaille s'écartent de plus de 30 % du standard!",
    });
}
return $exc;
```

n_excretion Annual N excreted by a specified number of animals.

```
Out(n_excretion_animal) * Out(animals);
```

tan_excretion Annual soluble N excreted by an animalgroup of selected poultry category.

```
if ( (not defined In(tan_fraction)) or lc In(tan_fraction) eq 'standard' ) {
  $TE->{"share_Nsol_" . Out(animalcategory)} * Out(n_excretion);
} else {
```

```
  my $tan = In(tan_fraction) / 100;
  if ( abs($tan - $TE->{"share_Nsol_" . Out(animalcategory)}) > 0.2) {
    writeLog({
        en => "The TAN fraction of N excretion entered for poultry differs from the standard by more than 20%
        de => "Der eingegebene TAN Anteil der N Ausscheidung für Geflügel weicht um mehr als 20% vom Standard
        fr => "La proportion du TAN des excrétions azotées saisies pour les volaille s'écartent de plus de 20
    });
  }
  return $tan * Out(n_excretion);
}
```

n_excretion_layers_growers_other_poultry Annual N excreted by poultry.

```
given ( Out(animalcategory) ) {
  when $_ eq 'layers' or $_ eq 'growers' or $_ eq 'other_poultry' {
    Out(n_excretion);
  }
  default {
    0;
  }
}
```

n_excretion_turkeys_broilers Annual N excreted by poultry.

```
given ( Out(animalcategory) ) {
  when $_ eq 'turkeys' or $_ eq 'broilers' {
    Out(n_excretion);
  }
  default {
    0;
  }
}
```

area_increase Factor on what barn size does increase the regularized minimal, limited to 0.5

```
if ( (Out(animals) < In(dimensioning_barn) ) and (Out(animals) != 0) ) {
  if ( In(dimensioning_barn) >= (Out(animals) * 1.5) ) {
    0.5;
  }
  else {
    In(dimensioning_barn) / Out(animals) - 1;
  }
}
else {
  0.0;
}
```

dimensioning_check Check if number of animals <= number of animal places.

```
if ( In(dimensioning_barn) < Out(animals) ) {
  writeLog({
    en => "The number of available animal places must be equal or higher than the number of animals.",
    de => "Anzahl Tierplätze muss grösser oder gleich der Anzahl der Tiere sein.",
    fr => "Le nombre de places dans l'étable doit être au moins égal au nombre d'animaux."
  });
  return "barn dimensioning too small";
}
else {
  return "barn dimensioning ok";
}
```

Technical Parameters

standard_N_excretion_layers 0.80
Annual standard N excretion for poultry category (layers) according to Flisch et al. (2009).

standard_N_excretion_growers 0.30
Annual standard N excretion for poultry category (growers) according to a decission of the

Group suisse bilanz.

standard_N_excretion_broilers 0.36
Annual standard N excretion for poultry category (broilers) according to Flisch et al. (2009).

standard_N_excretion_turkeys 1.4
Annual standard N excretion for poultry category according (turkeys) to Flisch et al. (2009).

standard_N_excretion_other_poultry 0.56
Annual standard N excretion for other poultry category according to Flisch et al. (2009).

share_Nsol_layers 0.6
Nsol content of excreta for layers. Derived from e.g. TODO

share_Nsol_growers 0.6
Nsol content of excreta for growers. Derived from e.g. TODO

share_Nsol_broilers 0.6
Nsol content of excreta for broilers. Derived from e.g. TODO

share_Nsol_turkeys 0.6
Nsol content of excreta for turkeys. Derived from e.g. TODO

share_Nsol_other_poultry 0.6
Nsol content of excreta for other poultry. Derived from e.g. TODO

2.64 Livestock::Poultry::Grazing

This process calculates the annual NH3 emission of free range poultry depending on the free range N excretion and the emission rate. The annual N excretion calculation is based on the grazing hours per day per year and the free range hours per day per year. The annual remaining N from free range poultry is calculated as the annual N excretion minus the annual NH3 emission.

2.64.1 References:

Menzi H, Shariatmadari H, Meierhans D, Wiedmer H 1997: Nähr- und Schadstoffbelastung von Geflügelausläufen. Agrarforschung 4: 361-364.

Inputs

free_range Average free range hours per day.

Outputs

free_range_days Average free range days per year.

```
if ( In(free_range) and lc In(free_range) eq 'yes' ) {
  return $TE->{'free_range_days_'.Val(animalcategory, Excretion)};
} else {
  return 0;
}
```

free_range_hours Average free range hours per day.

```
if ( In(free_range) and lc In(free_range) eq 'yes' ) {
  return $TE->{'free_range_hours_'.Val(animalcategory, Excretion)};
} else {
  return 0;
}
```

n_into_grazing Annual N excretion free_range (grazing).

```
Val(n_excretion, Excretion) *
Out(free_range_days) / 365 *
Out(free_range_hours) / 24;
```

tan_into_grazing Annual N excretion free_range (grazing).

```
Val(tan_excretion, Excretion) *
Out(free_range_days) / 365 *
Out(free_range_hours) / 24;
```

ef_nh3_ngrazing Free_range NH3 emission factor from poultry (grazing).

```
Tech(er_free_range);
```

nh3_ngrazing Annual free_range NH3 emission from poultry (grazing).

```
Out(tan_into_grazing) * Out(ef_nh3_ngrazing);
```

n2_ngrazing Annual free_range N2 emission from poultry (grazing).

```
Out(n_into_grazing) * Tech(er_n2_free_range);
```

no_ngrazing Annual free_range NO emission from poultry (grazing).

```
Out(n_into_grazing) * Tech(er_no_free_range);
```

n2o_ngrazing Annual free_range N2O emission from poultry (grazing).

```
Out(n_into_grazing) * Tech(er_n2o_free_range);
```

n_remain_grazing Annual N remaining free_range (on pasture, etc.).

```
Out(n_into_grazing) -
Out(nh3_ngrazing) -
Out(n2_ngrazing) -
Out(no_ngrazing) -
Out(n2o_ngrazing);
```

tan_remain_grazing Annual N remaining free_range (on pasture, etc.).

```
Out(tan_into_grazing) -
Out(nh3_ngrazing) -
Out(n2_ngrazing) -
Out(no_ngrazing) -
Out(n2o_ngrazing);
```

Technical Parameters

er_free_range 0.7
Emission rate for free range poultry, based on Menzi et al. (1997): 70% of TAN or 28% of Ntot

er_n2_free_range 0.0
Emission rate for manure application. Not considerd relevant

er_no_free_range 0.0055
Emission rate for manure application. Stehfest, Bouwman 2006

er_n2o_free_range 0.02
Emission rate for manure application. ICCP 2006: v4_11Ch_11; Tab11.1

free_range_days_layers 280
Average free range days per year.

free_range_hours_layers 2.88
Average free range hours per day, assumed is 12% of Day

free_range_days_growers 280
Average free range days per year.

free_range_hours_growers 2.88
Average free range hours per day, assumed is 12% of Day

free_range_days_turkeys 280
Average free range days per year.

free_range_hours_turkeys 0.96
Average free range hours per day, assumed is 4% of Day

free_range_days_other_poultry 280
Average free range days per year.

free_range_hours_other_poultry 0.96
Average free range hours per day, assumed is 12% of Day

free_range_days_broilers 280
Average free range days per year.

free_range_hours_broilers 0.96
Average free range hours per day, assumed is 4% of Day

2.65 Livestock::Poultry::Housing

This process calculates the NH3 emission in poultry housing depending on the N excretion and the housing systems. The NH3 emission is assumed to be proportional to the total N excretion of the animals because the contaminated surfaces will primarily drive emissions, which will remain active even when animals are on the pasture or exercise yard.

A proportional correction is applied according to the area per animal.

A correction is applied if the part of the day grazing is above a defined grazing hours per days.

2.65.1 Definition of System boundaries for the housing Process:

For housing systems with integrated exercise yards, it is difficult to distinguish between emissions from housing, exercise yard and storage. For these housingtypes the emission may be only validated for the sum of housing, exercise yard and storage emission.

Outputs

n_into_housing Annual N flux into the housing.

```
Val(n_excretion, Excretion) - Val(n_into_grazing, Grazing);
```

tan_into_housing Annual N flux into the housing.

```
Val(tan_excretion, Excretion) - Val(tan_into_grazing, Grazing);
```

ef_housing_before_air_scrubber NH3 emission factor before air scrubber removal of poultry housing systems.

```
my $ef = Val(er_housing, Housing::Type) *
          Val(c_area, Housing::Type) *
          Val(c_manure_removal_interval, Housing::Type) *
          Val(c_drinking_system, Housing::Type) *
          Val(c_free_factor_housing, Housing::CFreeFactor);
#FIXME: Add message if $ef > 1?
$ef = 1 unless $ef < 1;
return $ef;
```

ef_housing NH3 emission factor for poultry housing systems.

```
Out(ef_housing_before_air_scrubber) *
(1 - Val(red_air_scrubber, Housing::AirScrubber));
```

nh3_nhousing Annual NH3 emission from poultry housing systems per animal place.

```
Val(n_excretion, Excretion) * Out(ef_housing);
```

tan_air_scrubber Annual N of NH3 emission remaining in air scrubber from poultry housing systems.

```
if ( Val(air_scrubber, Housing::AirScrubber) eq 'biotrickling' ) {   Val(n_excretion, Excretion) *
  Out(ef_housing_before_air_scrubber) *
  Val(red_air_scrubber, Housing::AirScrubber);
} else {
  0;
}
```

n_outhousing_solid Annual N flux out of the housing excluding N remained in biotrickling filter.

```
Out(n_into_housing) - Out(nh3_nhousing) - Out(tan_air_scrubber);
```

tan_outhousing_solid Annual N flux out of the housing excluding N remained in biotrickling filter.

```
Out(tan_into_housing) - Out(nh3_nhousing) - Out(tan_air_scrubber);
```

2.66 Livestock::Poultry::Housing::Type

This process selects the emission rate for the specific housing types for poultry and the correction factors for the drinking system, and for the manure removal interval.

2.66.1 References

UNECE 2007. Guidance document on control techniques for preventing and abating emissions of ammonia. ECE/EB.AIR/WG.5/2007/13. Reidy B, Webb J, Misselbrook TH, Menzi H, Luesink HH, Hutchings NJ, Eurich-Menden B, Döhler H, Dämmgen U 2009. Comparison of models used for national agricultural ammonia emission inventories in Europe: litter-based manure systems. Atmospheric Environment 40, 1632-1640.

Inputs

housing_type Type of housing.

manure_removal_interval Manure removal interval by manure belt.

drinking_system Type of drinking system.

Outputs

housing_type Housing type (needed in other modules).

```
if ( Val(animalcategory, ..::Excretion) eq "layers" or
     Val(animalcategory, ..::Excretion) eq "growers" ) {
  return In(housing_type);
} else {
  if ( In(housing_type) eq "manure_belt_without_manure_belt_drying_system" ) {
    writeLog({
      en => "The category manure belt without manure belt drying system is not valid, please select the housi
      de => "Für Mastpoulets ist Kotbandentmistung als Aufstallung nicht vorgesehen. Wählen Sie stattdessen E
            . "(für die Berechnung wird Bodenhaltung gesetzt).",
      fr => "Pour des poulets à l‘engrais, il n'est pas prévu de stabulation avec "
            . "tapis d'évacuation du fumier. Choisissez plutôt ‘Litière profonde'."
    });
  }
  elsif ( In(housing_type) eq "manure_belt_with_manure_belt_drying_system" ) {
    writeLog({
      en => "Manure belt with manure belt drying system not valid, please select deep litter as housing type
      de => "Für Mastpoulets ist Kotbandentmistung als Aufstallung nicht vorgesehen. Wählen Sie stattdessen E
            . "(für die Berechnung wird Bodenhaltung gesetzt).",
      fr => "Pour des poulets à l‘engrais, il n'est pas prévu de stabulation avec "
            . "tapis d'évacuation du fumier. Choisissez plutôt ‘Litière profonde'."
    });
  }
  elsif ( In(housing_type) eq "deep_pit" ) {
    writeLog({
      en => "Deep pit not valid, please select deep litter as housing type for broilers.",
      de => "Für Mastpoulets ist Kotgrube als Aufstallung nicht vorgesehen. Wählen Sie stattdessen Bodenhaltu
            . "(für die Berechnung wird Bodenhaltung gesetzt).",
      fr => "Pour des poulets à l‘engrais, il n'est pas prévu de stabulation avec "
             . "fosse à déjections. Choisissez plutôt ‘Litière profonde'."
    });
  }
  return "deep_litter";
}
```

drinking_system Drinking system.

```
In(drinking_system);
```

er_housing Emission rate for the poultry housing type.

```
if ( Val(animalcategory, ..::Excretion) eq "layers" or
     Val(animalcategory, ..::Excretion) eq "growers" ) {
  given ( In(housing_type) ) {
    when "manure_belt_without_manure_belt_drying_system" {
      return Tech(er_housing_layers_growers_manure_belt_without_manure_belt_drying_system);
    }
    when "manure_belt_with_manure_belt_drying_system" {
      return Tech(er_housing_layers_growers_manure_belt_with_manure_belt_drying_system);
    }
    when "deep_pit" {
      return Tech(er_housing_layers_growers_deep_pit);
    }
    when "deep_litter" {
          return Tech(er_housing_layers_growers_deep_litter);
    }
  }
    } else {
  return Tech(er_housing_other_deep_litter);
}
```

c_manure_removal_interval Emission rate for the poultry housing type.

```
if ( In(housing_type) eq "manure_belt_without_manure_belt_drying_system" or
     In(housing_type) eq "manure_belt_with_manure_belt_drying_system" ) {
  given ( In(manure_removal_interval) ) {
    when "less_than_twice_a_month" {
     return Tech(c_manure_removal_interval_less_than_twice_a_month);
    }
    when "twice_a_month" {
     return Tech(c_manure_removal_interval_twice_a_month);
    }
    when "3_to_4_times_a_month" {
     return Tech(c_manure_removal_interval_3_to_4_times_a_month);
    }
    when "more_than_4_times_a_month" {
     return Tech(c_manure_removal_interval_more_than_4_times_a_month);
    }
    when "once_a_day" {
     return Tech(c_manure_removal_interval_once_a_day);
    }
    when "no_manure_belt" {
      writeLog({
        en => "The category 'No manure belt' is not applicable for housing systems with a manure belt!",
        de => "Kategorie 'keine Kotbandentmistung', ist nicht erlaubt bei Aufstallung, Kotbandentmistung!",
        fr => "La catégorie ‘Pas de tapis d'évacuation' n'est pas valable pour une "
              . "stabulation avec tapis d'évacuation du fumier!",
      });
     return Tech(c_manure_removal_interval_twice_a_month);  # default no correctios
    }
  }
}
else{                                          # Housing Type deep pit or deep litter
  if ( not (In(manure_removal_interval) eq "no_manure_belt") ) {
    writeLog({
      en => "Please enter under manure removal interval 'No manure belt' in combination with the housing syst
      de => "Bitte wählen Sie unter Entmistungsintervall 'keine Kotbandentmistung' in Kombination mit der Auf
      fr => "Sous ‘Fréquence d'évacuation du fumier', veuillez choisir la catégorie "
            . "‘Pas de tapis d'évacuation' en combinaison avec la stabulation ‘Litière "
            . "profonde' ou ‘Fosse à déjections' !",
    });
  }
  return 1; # default no correctios
}
```

c_drinking_system Correction factor for poultry drinking station.

```
if ( In(drinking_system) eq "drinking_nipples" ) {
   return Tech(c_drinking_nipples);
```

```
} elsif ( In(drinking_system) eq "bell_drinkers" ) {
   return Tech(c_bell_drinkers);
} else {
  writeLog({
    en => "Invalid 'drinking_system' entered!",
    de => "Ungültiges Tränkesystem eingegeben!",
    fr => "Ce type d'abreuvoir n'est pas valable!",
              });
  return 1.0;
}
```

c_area Correction factor for area per animal.

```
1 + (Val(area_increase, ..::Excretion) * Tech(k_area));
```

Technical Parameters

er_housing_layers_growers_manure_belt_without_manure_belt_drying_system 0.15
Emission rate for the poultry housing type, based on EAGER workshop January 2007: 15% of Ntot, converted using 60% Nsol and the emission rate of 25% based on TAN.

er_housing_layers_growers_manure_belt_with_manure_belt_drying_system 0.06
Emission rate for the poultry housing type, based on EAGER workshop January 2007: 6% of Ntot, converted using 60% Nsol and the emission rate of 10% based on TAN.

er_housing_layers_growers_deep_pit 0.30
Emission rate for the poultry housing type, based on EAGER workshop January 2007, UNECE 2007: 30% of Ntot, converted using 60% Nsol and the emission rate of 50% based on TAN.

er_housing_layers_growers_deep_litter 0.30
Emission rate for the poultry housing type, based on EAGER workshop January 2007, UNECE 2007: 30% of Ntot, converted using 60% Nsol and the emission rate of 50% based on TAN.

er_housing_other_deep_litter 0.12
Emission rate for the poultry housing type, based on Reidy et al. (2009): 12% of Ntot, converted using 60% Nsol and the emission rate of 20% based on TAN.

c_manure_removal_interval_less_than_twice_a_month 1.2
Emission rate for the poultry manure removal by droppings belt. Empirical assumption by Reidy/Menzi.

c_manure_removal_interval_twice_a_month 1
Emission rate for the poultry manure removal by droppings belt. Empirical assumption by Reidy/Menzi.

c_manure_removal_interval_3_to_4_times_a_month 0.8
Emission rate for the poultry manure removal by droppings belt. Empirical assumption by Reidy/Menzi.

c_manure_removal_interval_more_than_4_times_a_month 0.6
Emission rate for the poultry manure removal by droppings belt. Empirical assumption by Reidy/Menzi.

c_manure_removal_interval_once_a_day 0.4
Emission rate for the poultry manure removal by droppings belt. Empirical assumption by Reidy/Menzi.

c_drinking_nipples 1.0
Emission rate for the poultry drinking type standard version.

c_bell_drinkers 1.2
Emission rate for the poultry drinking type additional emission. Empirical assumption by

Reidy/Menzi.
TODO: Give better description!

k_area 0.5
Increasing factor for larger loose housing barns, +10 to +5

2.67 Livestock::Poultry::Housing::AirScrubber

This submodul calculates the annual NH3 reduction due to an exhaust air scrubber in housing systems according to the UNECE guideline 2007.

2.67.1 References:

UNECE 2007. Guidance document on control techniques for preventing and abating emissions of ammonia. ECE/EB.AIR/WG.5/2007/13.

Inputs

air_scrubber Exhaust air scrubber: none, acid, biotrickling_filter.

Outputs

air_scrubber air exhaust scrubber in housing systems.

```
In(air_scrubber);
```

red_air_scrubber Reduction factor for the emission due to the use of an air exhaust scrubber in housing systems.

```
given ( In(air_scrubber) ) {
  when 'acid' {
    return Tech(red_acid_air_scrubber);
  }
  when 'biotrickling' {
    return Tech(red_biotrickling_filter_air_scrubber);
  }
  when 'none' {
    return 0;
  }
  default {
    writeLog({
      en => "Invalid 'exhaust air scrubber' entered!",
      de => "Ungültige 'Abluftreinigung' eingegeben!",
      fr => "Entrée non valable pour ‘Traitement des effluents gazeux'!"
    });
    return 0;
  }
}
```

Technical Parameters

red_acid_air_scrubber 0.9
Reduction efficiency as compared to group-housed on fully and partly slatted floors (UNECE 2007, paragraph 71, table 5).

red_biotrickling_filter_air_scrubber 0.7
Reduction efficiency as compared to group-housed on fully and partly slatted floors (UNECE 2007, paragraph 71, table 5).

2.68 Livestock::Poultry::Housing::CFreeFactor

This process selects the emission rate for the specific housing types for poultry and the correction factors for the drinking system, and for the manure removal interval.

Inputs

free_correction_factor Factor to define free.

Outputs

c_free_factor_housing Free correction factor for NH3 housing emission.

```
if( In(free_correction_factor) // 0 != 0 ) {
  writeLog({
    en => "You have entered an additional emission mitigation measure for a poultry housing of "
          . In(free_correction_factor) . "\%!\n",
    de => "Sie haben eine zusätzliche emissionsmindernde Massnahme für einen Geflügelstall von "
          . In(free_correction_factor) . "\% eingegeben!\n",
    fr => "Vous avez introduit une mesure supplémentaire limitant les émissions provenant d'une "
          . "stabulation pour volaille de " . In(free_correction_factor) . "\%.\n"
  });
        return 1 - In(free_correction_factor) / 100;
}
else {
  return 1;
}
```

2.69 Livestock::Poultry::NxOx

TODO!

Outputs

n2_npoultry Annual N2 emission from poultry production (housing and grazing).

```
Val(n_into_housing, Housing) * Tech(er_n2)
```

no_npoultry Annual N2 emission from poultry production housing. (grazing not included)

```
Val(n_into_housing, Housing) * Tech(er_no)
```

n2o_npoultry Annual N2O emission from poultry production housing. (outdorr not included)

```
Val(n_into_housing, Housing) * Tech(er_n2o)
```

Technical Parameters

er_n2 0.025
Emission rate poultry for N2 poultry manure based on Ntot

er_no 0.001
Emission rate poultry for N2 poultry manure based on Ntot

er_n2o 0.001
Emission rate poultry for N2 poultry manure based on Ntot

2.70 Livestock::Equides::Excretion

This process calculated the annual N excretion of the animal categories listed above. The standard N excretion was taken from the official Swiss fertilizer guidelines. The Nsol content of the excreta is based on e.g. Peterson et al. (1998) or Burgos et al. (2005). These values were compiled on the basis of official feeding recommendations (Flisch et al. 2009) by H. Menzi.

2.70.1 References:

Burgos SA, Robinson PH, Fadel JG, DePeters EJ 2005. Ammonia volatilization potential: Prediction of urinary urea nitrogen output on lactating dairy cows. Agriculture, Ecosystems and Environment 111:261-269.

Peterson SO, Sommer SG, Aaes O, Soegaard K 1998. Ammonia losses from urine and dung of grazing cattle: effect of N intake. Atmospheric environment 32:295-300.

Flisch R, Sinaj S, Charles R, Richner W 2009. Grundlagen für die die Düngung im Acker- und Futterbau. Agrarforschung 16(2).

Inputs

animalcategory Animal category (horses younger than 3 years, horses older than 3 years, mules, ponies and asses).

animals Number of other animals for the selected type in barn.

inp_n_excretion Annual standard N excretion for animal category

tan_fraction TAN fraction of the annual standard N excretion

Outputs

animals Number of other animals for the selected type in barn.

```
In(animals);
```

animalcategory Animal category

```
In(animalcategory);
```

n_excretion_animal Annual standard N excretion for specified other animal category according to Flisch et al. (2009).

```
my $cat = In(animalcategory);
my $key = 'standard_N_excretion_' . $cat;
my $exc = $TE->{$key};
$exc = In(inp_n_excretion) unless ( (not defined In(inp_n_excretion)) or lc In(inp_n_excretion) eq 'standard'
if ( ($exc < 0.7 * $TE->{$key}) or ($exc > 1.3 * $TE->{$key})) {
    writeLog({
        en => "The N excretion entered for horses and other equides differs from the standard by more than 30
        de => "Die eingegebene N-Ausscheidung für Pferde und andere Equiden weicht um mehr als 30% vom Standa
        fr => "Les excrétions azotées saisies Chevaux et autres équidés s'écartent de plus de 30 % du standar
    });
}
return $exc;
```

n_excretion Annual N excreted by a specified number of animals.

```
Out(n_excretion_animal) * Out(animals);
```

tan_excretion Annual soluble N excreted by a specified number of animals.

```
if ( (not defined In(tan_fraction)) or lc In(tan_fraction) eq 'standard' ) {
  $TE->{"share_Nsol_" . Out(animalcategory)} * Out(n_excretion);
} else {
```

```
my $tan = In(tan_fraction);
$tan = In(tan_fraction) / 100;
if ( abs($tan - $TE->{"share_Nsol_" . Out(animalcategory)}) > 0.2) {
  writeLog({
      en => "The TAN fraction of N excretion entered for horses and other equids differs from the standard
      de => "Der eingegebene TAN Anteil der N Ausscheidung für Pferde und andere Equiden weicht um mehr als
      fr => "La proportion du TAN des excrétions azotées saisies pour les chevaux et autres équidés s'écart
  });
}
return $tan * Out(n_excretion);
}
```

Technical Parameters

standard_N_excretion_horses_younger_than_3yr 42
: Annual standard N excretion for other animal category (horses younger than 3 years) according to Flisch et al. (2009).

standard_N_excretion_horses_older_than_3yr 44
: Annual standard N excretion for other animal category (horses older than 3 years) according to Flisch et al. (2009).

standard_N_excretion_mules 25
: Annual standard N excretion for other animal category (mules) according to Flisch et al. (2009).

standard_N_excretion_ponies_and_asses 16
: Annual standard N excretion for other animal category (asses and ponies) according to Flisch et al. (2009).

share_Nsol_horses_younger_than_3yr 0.4
: Nsol content of excreta from horses younger than 3 years. Derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

share_Nsol_horses_older_than_3yr 0.4
: Nsol content of excreta from horses older than 3 years. Derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

share_Nsol_mules 0.4
: Nsol content of excreta from mules. Derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

share_Nsol_ponies_and_asses 0.4
: Nsol content of excreta from asses and ponies. Derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

2.71 Livestock::Equides::Housing

This process calculates the NH3 emission in equides housing depending on the N excretion and the housing systems. The NH3 emission is assumed to be proportional to the total N excretion of the animals because the contaminated surfaces will primarily drive emissions, which will remain active even when animals are on the pasture or exercise yard.

A proportional correction is applied according to the area per animal.

A correction is applied if the part of the day grazing is above a defined grazing hours per days.

2.71.1 Definition of System boundaries for the housing Process:

For housing systems with integrated exercise yards, it is difficult to distinguish between emissions from housing, exercise yard and storage. For these housingtypes the emission may be only validated for the sum of housing, exercise yard and storage emission.

Outputs

n_into_housing Annual N flux into the house.

```
Val(n_excretion, Excretion) -
Val(n_into_grazing, Grazing) -
Val(n_into_yard, Yard);
```

tan_into_housing Annual N flux as TAN into the house.

```
    Val(tan_excretion, Excretion) -
Val(tan_into_grazing, Grazing) -
Val(tan_into_yard, Yard);
```

nh3_nhousing Annual NH3 emission from equides housing systems.

```
my $c_housing = Val(c_grazing, Housing::KGrazing) *
                Tech(er_housing) *
                Val(c_free_factor_housing, Housing::CFreeFactor) ;
#FIXME: Check: Is it in any way even possible that nh3_nhousing > tan_into_housing???
$c_housing = 1 unless $c_housing < 1;
Out(tan_into_housing) * $c_housing;
```

n_outhousing Annual N flux out of the housing.

```
Out(n_into_housing) - Out(nh3_nhousing);
```

tan_outhousing Annual N flux as TAN out of the housing.

```
Out(tan_into_housing) - Out(nh3_nhousing);
```

n_outhousing_liquid Annual N flux out of housing, slurry or liquid fraction of N flux.

```
0
```

tan_outhousing_liquid Annual N flux as TAN out of housing, slurry or liquid fraction of N flux.

```
0
```

n_outhousing_solid Annual N flux out of housing, manure fraction of N flux.

```
Out(n_outhousing);
```

tan_outhousing_solid Annual N flux as TAN out of housing, manure fraction of N flux.

```
Out(tan_outhousing);
```

Technical Parameters

er_housing 0.275
Emission rate for loose housing with liquid, solid manure system is assumed (for TAN 0.275 and Nsol 40%).

2.72 Livestock::Equides::Housing::CFreeFactor

TODO

Inputs

free_correction_factor Factor to define free.

Outputs

c_free_factor_housing Free correction factor for NH3 housing emission.

```
if ( In(free_correction_factor) // 0 != 0 ) {
  writeLog({
    en=>"You have entered an additional emission mitigation measure for a housing of the "
        . "category horses and other equids of " . In(free_correction_factor)
        . "\%!\n",
    de=>"Sie haben eine zusätzliche emissionsmindernde Massnahme für einen Stall der "
        . "Kategorie Pferde und andere Equiden von " . In(free_correction_factor)
        . "\% eingegeben!\n",
    fr=>"Vous avez introduit une mesure supplémentaire limitant les émissions dans les "
        ."stabulations pour chevaux et autres équidés " . In(free_correction_factor)
        . "\%.\n"
    });
  return 1 - In(free_correction_factor) / 100;
}
else {
  return 1;
}
```

2.73 Livestock::Equides::Grazing

This process calculates the annual NH3 emission from grazing of equides (horses, mules, asses) based on the total N excreted on the pastures. The N excreted is calculated according to the time the animals spend on the pasture. It assumes that the excretions on the pasture are proportional to the time the animals are grazed.

2.73.1 References:

Bussink DW 1992. Ammonia volatilization from grassland receiving nitrogen fertilizer and rotationally grazed by dairy cattle. Fertilizer Research 33:257-265.

Bussink DW 1994. Relationship between ammonia volatilization and nitrogen fertilizer application rate, intake and excretion of herbage nitrogen by cattle on grazed swards. Fertilizer Research 38:111-121.

Jarvis SC, Hatch DJ, Lockyer DR 1989. Ammonia fluxes from grazed grassland: annual losses from cattle production systems and their relation to nitrogen inputs. Journal of Agricultural Science 113:99-108.

Peterson SO, Sommer SG, Aaes O, Soegaard K 1998. Ammonia losses from urine and dung of grazing cattle: effect of N intake. Atmospheric environment 32:295-300.

Ross CA, Jarvis SC 2001. Measurement of emission and deposition pattern of ammonia from urine in grass swards. Atmospheric environment 35:867-875.

Outputs

share_into_grazing Share of annual N excretion into grazing.

```
(Val(grazing_days, Outdoor) - Val(days_with_grazing_and_yard, Outdoor)) / 365 *
Val(grazing_hours, Outdoor) / 24 +
# access to grazing only - days with yard and grazing
Val(days_with_grazing_and_yard, Outdoor) / 365 *
(Val(grazing_hours, Outdoor) - Val(hours_with_grazing_and_yard, Outdoor)) / 24 +
# access to yard and grazing (shared 50/50)
0.5 *
Val(days_with_grazing_and_yard, Outdoor) / 365 *
Val(hours_with_grazing_and_yard, Outdoor) / 24;
```

n_into_grazing Annual N excretion during grazing for equides.

```
Val(n_excretion, Excretion) *
Out(share_into_grazing);
```

tan_into_grazing Annual solable N (TAN) excretion during grazing for equides.

```
Val(tan_excretion,Excretion) *
Out(share_into_grazing);
```

ef_nh3_ngrazing Annual total NH3 emission from all grazing dairy cows.

```
Tech(er_equides_grazing);
```

nh3_ngrazing Annual NH3 emission from equides from grazing.

```
Out(tan_into_grazing) * Out(ef_nh3_ngrazing);
```

n2_ngrazing Annual total N2 emission from all grazing dairy cows.

```
Out(n_into_grazing) * Tech(er_n2_equides_grazing);
```

no_ngrazing Annual total N2 emission from all grazing dairy cows.

```
Out(n_into_grazing) * Tech(er_no_equides_grazing);
```

n2o_ngrazing Annual total N2O emission from all grazing dairy cows.

```
Out(n_into_grazing) * Tech(er_n2o_equides_grazing);
```

n_remain_grazing Annual N input on pastures.

```
Out(n_into_grazing) -
Out(nh3_ngrazing) -
Out(n2_ngrazing) -
Out(no_ngrazing) -
Out(n2o_ngrazing);
```

tan_remain_grazing Annual N input on pastures.

```
Out(tan_into_grazing) -
Out(nh3_ngrazing) -
Out(n2_ngrazing) -
Out(no_ngrazing) -
Out(n2o_ngrazing);
```

Technical Parameters

er_equides_grazing 0.125
Emission rate for the calculation of the annual NH3 emission during grazing of equides. 5% Ntot (conversion with a protion of Nsol of 40%: EF 12.5% TAN). The emission rate is derived from Bussink et al. (1992, 1994), Jarvis et al. (1989), Peterson et al. (1998) and Ross and Jarvis (2001). (taking into account the generally low fertilization rate of Swiss pastures.)

er_n2_equides_grazing 0.0
Emission rate for manure application. Not considerd relevant

er_no_equides_grazing 0.0055
Emission rate for manure application. Stehfest, Bouwman 2006

er_n2o_equides_grazing 0.01
Emission rate for manure application. ICCP 2006: v4_11Ch_11; Tab11.1

2.74 Livestock::Equides::Outdoor

Input parameters for Grazing, also used in module Yard.

Inputs

grazing_days Average grazing days per year.

grazing_hours Average grazing hours per day.

yard_days Access to exercise yard in days per year.

yard_hours Access to exercise yard in hours per day.

floor_properties_exercise_yard Floor properties (solid_floor, unpaved_floor, paddock_or_pasture_used_as_exercise_yard).

free_correction_factor Factor to define free ?

Outputs

grazing_hours Grazing hours per day.

```
In(grazing_hours);
```

grazing_days Grazing days per year.

```
In(grazing_days);
```

yard_hours Yard hours per day.

```
In(yard_hours);
```

yard_days Yard days per year.

```
In(yard_days);
```

days_with_grazing_and_yard Number of Days whith access to yard and pasture

```
if( (Out(grazing_days) + Out(yard_days)) > 365 ){
  return Out(grazing_days) + Out(yard_days) - 365;
} else {
  return 0;
}
```

hours_with_grazing_and_yard Number of Hours per Day whith access to yard and pasture

```
if( (Out(grazing_hours) + Out(yard_hours)) > 24 ){
  return Out(grazing_hours) + Out(yard_hours) - 24;
} else {
  return 0;
}
```

floor_properties_exercise_yard Exercise yard floor properties.

```
In(floor_properties_exercise_yard);
```

c_free_factor_yard Free correction factor of the Emission rate for the Yard.

```
if ( In(free_correction_factor) // 0 != 0 ) {
    writeLog({en=>"You have entered an additional emission mitigation measure for the exercise yard of "
                  . "the category horses and other equids of " . In(free_correction_factor)
                  . "\%!\n",
              de=>"Sie haben eine zusätzliche emissionsmindernde Massnahme für einen Laufhof der Kategorie "
                  . "Pferde und andere Equiden von "
                  . In(free_correction_factor)
                  . "\% eingegeben!\n",
              fr=>"Vous avez introduit une mesure supplémentaire limitant les émissions provenant d'un "
      . "parcours extérieur pour chevaux et autres équidés de " . In(free_correction_factor)
                  . "\%.\n" });
```

```
    return 1 - In(free_correction_factor) / 100;
} else {
  return 1;
}
```

2.75 Livestock::Equides::Housing::KGrazing

This process calculates the correction factor for the non proportional change of the housing emission according to the grazing hours per day. Source is Phillips et al. (1998) and Gilhespy et al. (2006) empirical estimation was done by Thomas Kupper.

Outputs

c_grazing The correction factor for the reduction of the housing emission depending on the number of grazing hours per day and the grazing days per year.

```
my $k_grazing = Tech(k_grazing_a) * exp(Tech(k_grazing_b) * Val(grazing_hours, ..::Outdoor));
# scale with ratio grazing_days per year
($k_grazing - 1) * Val(grazing_days, ..::Outdoor) / 365 + 1;
```

Technical Parameters

k_grazing_a 0.9989
Coefficient a of empirical estimation c = a * exp(b * grazing_hours).

k_grazing_b 0.0403
Coefficient a of empirical estimation c = a * exp(b * grazing_hours).

2.76 Livestock::Equides::Yard

2.76.1 References

Keck M 1997: Ammonia emission and odour thresholds of cattle houses with exercise yards. In: Voermans JAM and Monteny GJ (Eds): ”Ammonia and odour emissions from animal production facilities”, Proc. International Symposium, Vinkeloord, NL, 6-10 October 1997, 349-354. Misselbrook TH, Webb J, Chadwick DR, Ellis S, Pain BF 2001. Gaseous emissions from grazing concrete yards used by livestock. Atmospheric Environment 35:5331-5338.

Outputs

c_floor_properties_exercise_yard Correction factor for the emission due to the use of the floor properties in housing systems.

```
given ( Val(floor_properties_exercise_yard, Outdoor) ) {
  when 'unpaved_floor' {
    1 - Tech(red_floor_properties_unpaved_floor);
  }
  when 'solid_floor' {
    1 - Tech(red_floor_properties_solid_floor);
  }
  when 'paddock_or_pasture_used_as_exercise_yard' {
    1 - Tech(red_floor_properties_paddock_or_pasture_used_as_exercise_yard);
  }
  default {
    1;
  }
}
```

share_into_yard Share of annual N excretion into yard.

```
(Val(yard_days, Outdoor) - Val(days_with_grazing_and_yard, Outdoor)) / 365 *
Val(yard_hours, Outdoor) / 24 +
# access to yard only - days with yard and grazing
Val(days_with_grazing_and_yard, Outdoor) / 365 *
(Val(yard_hours, Outdoor) - Val(hours_with_grazing_and_yard, Outdoor)) / 24 +
# access to yard and grazing (shared 50/50)
0.5 *
Val(days_with_grazing_and_yard, Outdoor) / 365 *
Val(hours_with_grazing_and_yard, Outdoor) / 24;
```

n_into_yard Annual N excretion on yard for a defined animal category.

```
Val(n_excretion, Excretion) *
Out(share_into_yard);
```

tan_into_yard Annual soluble N excretion on yard for a defined animal category.

```
Val(tan_excretion, Excretion) *
Out(share_into_yard);
```

ef_nh3_nyard NH3 emission factor for dairy cow yard.

```
Tech(er_yard) *
Out(c_floor_properties_exercise_yard) *
Val(c_free_factor_yard, Outdoor);
```

nh3_nyard Annual NH3 emission from yard.

```
Out(tan_into_yard) * Out(ef_nh3_nyard);
```

n_outyard_liquid Annual N flux from liquid part out of yard.

```
0;
```

tan_outyard_liquid Annual N flux as TAN from liquid part out of yard into storage.

```
0;
```

n_outyard_solid Annual N flux from solid part out of yard.

```
Out(n_into_yard) - Out(nh3_nyard);
```

tan_outyard_solid Annual N flux as TAN from solid part out of yard into storage.

```
Out(tan_into_yard) - Out(nh3_nyard);
```

Technical Parameters

er_yard 0.35
Emission rate for TAN on yard. Empirical estimation Kupper/Menzi, Keck(1997, Misselbrook et al. (2001)

red_floor_properties_unpaved_floor 0.5
Reduction efficiency according to Reidy and Menzi.

red_floor_properties_solid_floor 0.0
Reduction efficiency according to Reidy and Menzi.

red_floor_properties_paddock_or_pasture_used_as_exercise_yard 0.9
Reduction efficiency according to Reidy and Menzi.

2.77 Livestock::Equides::NxOx

TODO!

Outputs

n2_nsolid Annual N2 emission from equides housing and yard (production).

```
(Val(n_into_housing, Housing) + Val(n_into_yard, Yard)) *
Tech(er_n2_nsolid);
```

no_nsolid Annual NO emission from equides housing and yard (production).

```
(Val(n_into_housing, Housing) + Val(n_into_yard, Yard)) *
Tech(er_no_nsolid);
```

n2o_nsolid Annual N2O emission from equides housing and yard (production).

```
(Val(n_into_housing, Housing) + Val(n_into_yard, Yard)) *
Tech(er_n2o_nsolid);
```

Technical Parameters

er_n2_nsolid 0.05
Emission rate for N2 based on Ntot

er_no_nsolid 0.01
Emission rate for N2 based on Ntot

er_n2o_nsolid 0.01
Emission rate for N2 based on Ntot

2.78 Livestock::SmallRuminants::Excretion

This process calculated the annual N excretion of small ruminats. The standard N excretion was taken from the official Swiss fertilizer guidelines. The Nsol content of the excreta is based on e.g. Peterson et al. (1998) or Burgos et al. (2005). These values were compiled on the basis of official feeding recommendations (Flisch et al. 2009) by H. Menzi.

2.78.1 References:

Burgos SA, Robinson PH, Fadel JG, DePeters EJ 2005. Ammonia volatilization potential: Prediction of urinary urea nitrogen output on lactating dairy cows. Agriculture, Ecosystems and Environment 111:261-269.

Peterson SO, Sommer SG, Aaes O, Soegaard K 1998. Ammonia losses from urine and dung of grazing cattle: effect of N intake. Atmospheric environment 32:295-300.

Flisch R, Sinaj S, Charles R, Richner W 2009. Grundlagen für die die Düngung im Acker- und Futterbau. Agrarforschung 16(2).

Inputs

animalcategory Animal category (Fattening sheep, milksheep and goats).

animals Number of other animals for the selected type in barn.

inp_n_excretion Annual standard N excretion for a dairy cow

tan_fraction TAN fraction of the annual standard N excretion

Outputs

animals Number of small ruminants for the selected type in barn.

```
In(animals);
```

animalcategory Animal category

```
In(animalcategory);
```

n_excretion_animal Annual standard N excretion for specified other animal category according to Flisch et al. (2009).

```
my $cat = Out(animalcategory);
my $key = 'standard_N_excretion_' . $cat;
my $exc = $TE->{$key};
$exc = In(inp_n_excretion) unless ( (not defined In(inp_n_excretion)) or lc In(inp_n_excretion) eq 'standard'
if ( ($exc < 0.7 * $TE->{$key}) or ($exc > 1.3 * $TE->{$key})) {
    writeLog({
        en => "The N excretion entered for small ruminants differs from the standard by more than 30%!",
        de => "Die eingegebene N-Ausscheidung für Kleinwiederkäuer weicht um mehr als 30% vom Standard ab!",
        fr => "Les excrétions azotées saisies pour les petits ruminants s'écartent de plus de 30 % du standar
    });
}
return $exc;
```

n_excretion Annual N excreted by a specified number of small ruminants.

```
Out(n_excretion_animal) * Out(animals);
```

tan_excretion Annual soluble N excreted by a specified number of small ruminants.

```
if ( (not defined In(tan_fraction)) or lc In(tan_fraction) eq 'standard' ) {
  $TE->{"share_Nsol_" . Out(animalcategory)} * Out(n_excretion);
} else {
  my $tan = In(tan_fraction);
  $tan = In(tan_fraction) / 100;
```

```
    if ( abs($tan - $TE->{"share_Nsol_" . Out(animalcategory)}) > 0.2) {
      writeLog({
          en => "The TAN fraction of N excretion entered for small ruminants differs from the standard by more
          de => "Der eingegebene TAN Anteil der N Ausscheidung für Kleinwiederkäuer weicht um mehr als 20% vom
          fr => "La proportion du TAN des excrétions azotées saisies pour les petits ruminants s'écartent de pl
      });
    }
    return $tan * Out(n_excretion);
  }
```

Technical Parameters

standard_N_excretion_goats 17
: Annual standard N excretion for goats according to Flisch et al. (2009).

standard_N_excretion_fattening_sheep 15
: Annual standard N excretion for fattening sheep according to Flisch et al. (2009).

standard_N_excretion_milksheep 20
: Annual standard N excretion for milksheep according to Flisch et al. (2009).

share_Nsol_goats 0.4
: Nsol content of excreta from goats. Derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

share_Nsol_fattening_sheep 0.4
: Nsol content of excreta from fattening sheep. Derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

share_Nsol_milksheep 0.4
: Nsol content of excreta from milksheep. Derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

2.79 Livestock::SmallRuminants::Housing

This process calculates the NH3 emission in small ruminants housing depending on the N excretion and the housing systems. The NH3 emission is assumed to be proportional to the total N excretion of the animals because the contaminated surfaces will primarily drive emissions, which will remain active even when animals are on the pasture or exercise yard.

A proportional correction is applied according to the area per animal.

A correction is applied if the part of the day grazing is above a defined grazing hours per days.

2.79.1 Definition of System boundaries for the housing Process:

For housing systems with integrated exercise yards, it is difficult to distinguish between emissions from housing, exercise yard and storage. For these housingtypes the emission may be only validated for the sum of housing, exercise yard and storage emission.

Outputs

n_into_housing Annual N flux into the house.

```
Val(n_excretion, Excretion) -
Val(n_into_grazing, Grazing);
```

tan_into_housing Annual N flux as TAN into the house.

```
     Val(tan_excretion, Excretion) -
 Val(tan_into_grazing, Grazing);
```

ef_nh3_nhousing NH3 emission factor for small ruminants housing systems.

```
my $ef_nh3 = Tech(er_housing) *
             Val(c_grazing, Housing::KGrazing) *
             Val(c_free_factor_housing, Housing::CFreeFactor);
#FIXME: Check: Is it in any way even possible that $ef_nh3 > 1???
$ef_nh3 = 1 unless $ef_nh3 < 1;
return $ef_nh3;
```

nh3_nhousing Annual NH3 emission from small ruminants housing systems per animal place.

```
Out(tan_into_housing) * Out(ef_nh3_nhousing);
```

n_outhousing Annual N flux out of the housing.

```
Out(n_into_housing) - Out(nh3_nhousing);
```

tan_outhousing Annual N flux as TAN out of the housing.

```
Out(tan_into_housing) - Out(nh3_nhousing);
```

n_outhousing_liquid Annual N flux out of housing, slurry or liquid fraction of N flux.

```
0
```

tan_outhousing_liquid Annual N flux as TAN out of housing, slurry or liquid fraction of N flux.

```
0
```

n_outhousing_solid Annual N flux out of housing, manure fraction of N flux.

```
Out(n_outhousing);
```

tan_outhousing_solid Annual N flux as TAN out of housing, manure fraction of N flux.

```
Out(tan_outhousing);
```

Technical Parameters

er_housing 0.275
Emission rate for loose housing with liquid, solid manure system is assumed (for TAN 0.275 and Nsol 40%).

2.80 Livestock::SmallRuminants::Housing::CFreeFactor

TODO

Inputs

free_correction_factor Factor to define free.

Outputs

c_free_factor_housing Free correction factor for NH3 housing emission.

```
if ( In(free_correction_factor) // 0 != 0 ) {
  writeLog({
    en => "You have entered an additional emission mitigation measure for a housing of the "
          . "category small ruminants of " . In(free_correction_factor)
          . "\%!\n",
    de => "Sie haben eine zusätzliche emissionsmindernde Massnahme für einen Stall der "
          . "Kategorie Kleinwiederkäuer von " . In(free_correction_factor)
          . "\% eingegeben!\n",
    fr => "Vous avez introduit une mesure supplémentaire limitant les émissions dans les "
          ."stabulations de la catégorie de petits ruminants de " . In(free_correction_factor)
          . "\%.\n"
    });
  return 1 - In(free_correction_factor) / 100;
}
else {
  return 1;
}
```

2.81 Livestock::SmallRuminants::Housing::KGrazing

This process calculates the correction factor for the non proportional change of the housing emission according to the grazing hours per day. Source is Phillips et al. (1998) and Gilhespy et al. (2006) empirical estimation was done by Thomas Kupper.

Outputs

c_grazing The correction factor for the reduction of the housing emission depending on the number of grazing hours per day and the grazing days per year.

```
my $k_grazing = Tech(k_grazing_a) * exp(Tech(k_grazing_b) * Val(grazing_hours, ..::Grazing));
# scale with ratio grazing_days per year
($k_grazing - 1) * Val(grazing_days, ..::Grazing) / 365 + 1;
```

Technical Parameters

k_grazing_a 0.9989
Coefficient a of empirical estimation c = a * exp(b * grazing_hours).

k_grazing_b 0.0403
Coefficient a of empirical estimation c = a * exp(b * grazing_hours).

2.82 Livestock::SmallRuminants::Grazing

This process calculates the annual NH3 emission from grazing goats, fattening sheep and milk-sheep based on the total N excreted on the pastures. The N excreted is calculated according to the time the animals spend on the pasture. It assumes that the excretions on the pasture are proportional to the time the animals are grazed.

2.82.1 References:

Bussink DW 1992. Ammonia volatilization from grassland receiving nitrogen fertilizer and rotationally grazed by dairy cattle. Fertilizer Research 33:257-265.

Bussink DW 1994. Relationship between ammonia volatilization and nitrogen fertilizer application rate, intake and excretion of herbage nitrogen by cattle on grazed swards. Fertilizer Research 38:111-121.

Jarvis SC, Hatch DJ, Lockyer DR 1989. Ammonia fluxes from grazed grassland: annual losses from cattle production systems and their relation to nitrogen inputs. Journal of Agricultural Science 113:99-108.

Peterson SO, Sommer SG, Aaes O, Soegaard K 1998. Ammonia losses from urine and dung of grazing cattle: effect of N intake. Atmospheric environment 32:295-300.

Ross CA, Jarvis SC 2001. Measurement of emission and deposition pattern of ammonia from urine in grass swards. Atmospheric environment 35:867-875.

Inputs

grazing_days Average grazing days per year.

grazing_hours Average grazing hours per day.

Outputs

grazing_hours Grazing hours per day.

```
In(grazing_hours);
```

grazing_days Grazing days per year.

```
In(grazing_days);
```

n_into_grazing Annual N excretion during grazing for small ruminants.

```
Val(n_excretion,Excretion) *
In(grazing_days)  / 365 *
In(grazing_hours) /  24;
```

tan_into_grazing Annual solable N (TAN) excretion during grazing for small ruminants.

```
Val(tan_excretion,Excretion) *
In(grazing_days)  / 365 *
In(grazing_hours) /  24;
```

ef_nh3_ngrazing Annual total NH3 emission from all grazing dairy cows.

```
Tech(er_small_ruminants_grazing);
```

nh3_ngrazing Annual NH3 emission from small ruminants from grazing.

```
Out(tan_into_grazing) * Out(ef_nh3_ngrazing);
```

n2_ngrazing Annual total N2 emission from all grazing dairy cows.

```
Out(n_into_grazing) * Tech(er_n2_small_ruminants_grazing);
```

no_ngrazing Annual total N2 emission from all grazing dairy cows.

```
Out(n_into_grazing) * Tech(er_no_small_ruminants_grazing);
```

n2o_ngrazing Annual total N2O emission from all grazing dairy cows.

```
Out(n_into_grazing) * Tech(er_n2o_small_ruminants_grazing);
```

n_remain_grazing Annual N input on pastures.

```
Out(n_into_grazing) -
Out(nh3_ngrazing) -
Out(n2_ngrazing) -
Out(no_ngrazing) -
Out(n2o_ngrazing);
```

tan_remain_grazing Annual N input on pastures.

```
Out(tan_into_grazing) -
Out(nh3_ngrazing) -
Out(n2_ngrazing) -
Out(no_ngrazing) -
Out(n2o_ngrazing);
```

Technical Parameters

er_small_ruminants_grazing 0.125
Emission rate for the calculation of the annual NH3 emission during grazing of small ruminants. The emission rate is derived from Bussink et al. (1992, 1994), Jarvis et al. (1989), Peterson et al. (1998) and Ross and Jarvis (2001). (taking into account the generally low fertilization rate of Swiss pastures.)

er_n2_small_ruminants_grazing 0.0
Emission rate for manure application. Not considerd relevant

er_no_small_ruminants_grazing 0.0055
Emission rate for manure application. Stehfest, Bouwman 2006

er_n2o_small_ruminants_grazing 0.01
Emission rate for manure application. ICCP 2006: v4_11Ch_11; Tab11.1

2.83 Livestock::SmallRuminants::NxOx

TODO!

Outputs

n2_nsolid Annual N2 emission from other animals housing and storage.

```
Val(n_into_housing, Housing) * Tech(er_n2_nsolid);
```

no_nsolid Annual NO emission from other animals housing and storage.

```
Val(n_into_housing, Housing) * Tech(er_no_nsolid);
```

n2o_nsolid Annual N2O emission from other animals housing and storage.

```
Val(n_into_housing, Housing) * Tech(er_n2o_nsolid);
```

Technical Parameters

er_n2_nsolid 0.05
Emission rate for N2 based on Ntot

er_no_nsolid 0.01
Emission rate for N2 based on Ntot

er_n2o_nsolid 0.01
Emission rate for N2 based on Ntot

2.84 Livestock::RoughageConsuming::Excretion

This process calculated the annual N excretion of small ruminats. The standard N excretion was taken from the official Swiss fertilizer guidelines. The Nsol content of the excreta is based on e.g. Peterson et al. (1998) or Burgos et al. (2005). These values were compiled on the basis of official feeding recommendations (Flisch et al. 2009) by H. Menzi.

2.84.1 References:

Burgos SA, Robinson PH, Fadel JG, DePeters EJ 2005. Ammonia volatilization potential: Prediction of urinary urea nitrogen output on lactating dairy cows. Agriculture, Ecosystems and Environment 111:261-269.

Peterson SO, Sommer SG, Aaes O, Soegaard K 1998. Ammonia losses from urine and dung of grazing cattle: effect of N intake. Atmospheric environment 32:295-300.

Flisch R, Sinaj S, Charles R, Richner W 2009. Grundlagen für die die Düngung im Acker- und Futterbau. Agrarforschung 16(2).

Inputs

animalcategory Animal category (Fattening sheep, milksheep and goats).

animals Number of other animals for the selected type in barn.

inp_n_excretion Annual standard N excretion for a dairy cow

tan_fraction TAN fraction of the annual standard N excretion

Outputs

animals Number of small ruminants for the selected type in barn.

```
In(animals);
```

animalcategory Animal category

```
In(animalcategory);
```

n_excretion_animal Annual standard N excretion for specified other animal category according to Flisch et al. (2009).

```
my $cat = Out(animalcategory);
my $key = 'standard_N_excretion_' . $cat;
my $exc = $TE->{$key};
$exc = In(inp_n_excretion) unless ( (not defined In(inp_n_excretion)) or lc In(inp_n_excretion) eq 'standard'
if ( ($exc < 0.7 * $TE->{$key}) or ($exc > 1.3 * $TE->{$key})) {
    writeLog({
        en => "The N excretion entered for other roughage consuming animals differs from the standard by more
        de => "Die eingegebene N-Ausscheidung für andere Raufutterverzehrer weicht um mehr als 30% vom Standa
        fr => "Les excrétions azotées saisies autres animaux consommant des fourrages grossiers s'écartent de
    });
}
return $exc;
```

n_excretion Annual N excreted by a specified number of small ruminants.

```
Out(n_excretion_animal) * Out(animals);
```

tan_excretion Annual soluble N excreted by a specified number of small ruminants.

```
if ( (not defined In(tan_fraction)) or lc In(tan_fraction) eq 'standard' ) {
  $TE->{"share_Nsol_" . Out(animalcategory)} * Out(n_excretion);
} else {
  my $tan = In(tan_fraction);
  $tan = In(tan_fraction) / 100;
```

```
    if ( abs($tan - $TE->{"share_Nsol_" . Out(animalcategory)}) > 0.2) {
      writeLog({
          en => "The TAN fraction of N excretion entered for other roughage consuming animals differs from the
          de => "Der eingegebene TAN Anteil der N Ausscheidung für andere Raufutterverzehrer weicht um mehr als
          fr => "La proportion du TAN des excrétions azotées saisies pour les autres animaux consommant des fou
      });
    }
    return $tan * Out(n_excretion);
  }
```

Technical Parameters

standard_N_excretion_fallow_deer 20
: Annual standard N excretion for fallow deer according to Agridea, BLW (2014)

standard_N_excretion_red_deer 40
: Annual standard N excretion for according to Agridea, BLW (2014)

standard_N_excretion_wapiti 80
: Annual standard N excretion for according to Agridea, BLW (2014)

standard_N_excretion_bison_older_than_3yr 60
: Annual standard N excretion for according to Agridea, BLW (2014)

standard_N_excretion_bison_younger_than_3yr 20
: Annual standard N excretion for according to Agridea, BLW (2014)

standard_N_excretion_lama_older_than_2yr 17
: Annual standard N excretion for lama older than 2 years according to Agridea, BLW (2014)

standard_N_excretion_lama_younger_than_2yr 11
: Annual standard N excretion for lama younger than 2 yearsaccording to Agridea, BLW (2014)

standard_N_excretion_alpaca_older_than_2yr 11
: Annual standard N excretion for alpaca older than 2 years according to Agridea, BLW (2014)

standard_N_excretion_alpaca_younger_than_2yr 7
: Annual standard N excretion for according to Agridea, BLW (2014)

standard_N_excretion_rabbit_doe_kits 2.6
: Annual standard N excretion for rabbit doe including kits (young 35 day) according to Agridea, BLW (2014)

standard_N_excretion_rabbit_young 0.79
: Annual standard N excretion for young rabbit (older than 35 day) according to Agridea, BLW (2014)

share_Nsol_fallow_deer 0.4
: Nsol content of excreta from goats. Assumtion by Menzi, Reidy 2004, Derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

share_Nsol_red_deer 0.4
: Nsol content of excreta from goats. Assumtion by Menzi, Reidy 2004, Derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

share_Nsol_wapiti 0.4
: Nsol content of excreta from goats. Assumtion by Menzi, Reidy 2004, Derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

share_Nsol_bison_older_than_3yr 0.4
: Nsol content of excreta from goats. Assumtion by Menzi, Reidy 2004, Derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

share_Nsol_bison_younger_than_3yr 0.4
Nsol content of excreta from goats. Assumtion by Menzi, Reidy 2004, Derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

share_Nsol_lama_older_than_2yr 0.4
Nsol content of excreta from goats. Assumtion by Menzi, Reidy 2004, Derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

share_Nsol_lama_younger_than_2yr 0.4
Nsol content of excreta from goats. Assumtion by Menzi, Reidy 2004, Derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

share_Nsol_alpaca_older_than_2yr 0.4
Nsol content of excreta from goats. Assumtion by Menzi, Reidy 2004, Derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

share_Nsol_alpaca_younger_than_2yr 0.4
Nsol content of excreta from goats. Assumtion by Menzi, Reidy 2004, Derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

share_Nsol_rabbit_doe_kits 0.4
Nsol content of excreta from rabbit doe including kits. Menzi, Reidy (2004), # ?derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

share_Nsol_rabbit_young 0.4
Nsol content of excreta from young rabbit (older aprox 35 day). Menzi, Reidy (2004), # ?derived from e.g. Peterson et al. (1998) or Burgos et al. (2005).

2.85 Livestock::RoughageConsuming::Housing

This process calculates the NH3 emission in small ruminants housing depending on the N excretion and the housing systems. The NH3 emission is assumed to be proportional to the total N excretion of the animals because the contaminated surfaces will primarily drive emissions, which will remain active even when animals are on the pasture or exercise yard.

A proportional correction is applied according to the area per animal.

A correction is applied if the part of the day grazing is above a defined grazing hours per days.

2.85.1 Definition of System boundaries for the housing Process:

For housing systems with integrated exercise yards, it is difficult to distinguish between emissions from housing, exercise yard and storage. For these housingtypes the emission may be only validated for the sum of housing, exercise yard and storage emission.

Outputs

n_into_housing Annual N flux into the house.

```
Val(n_excretion, Excretion) -
Val(n_into_grazing, Grazing);
```

tan_into_housing Annual N flux as TAN into the house.

```
Val(tan_excretion, Excretion) -
Val(tan_into_grazing, Grazing);
```

ef_nh3_nhousing NH3 emission factor for roughage consuming housing systems.

```
my $ef_nh3 = Tech(er_housing) *
             Val(c_grazing, Housing::KGrazing) *
             Val(c_free_factor_housing, Housing::CFreeFactor);
#FIXME: Check: Is it in any way even possible that $ef_nh3 > 1???
$ef_nh3 = 1 unless $ef_nh3 < 1;
return $ef_nh3;
```

nh3_nhousing Annual NH3 emission from small ruminants housing systems per animal place.

```
Out(tan_into_housing) * Out(ef_nh3_nhousing);
```

n_outhousing Annual N flux out of the housing.

```
Out(n_into_housing) - Out(nh3_nhousing);
```

tan_outhousing Annual N flux as TAN out of the housing.

```
Out(tan_into_housing) - Out(nh3_nhousing);
```

n_outhousing_liquid Annual N flux out of housing, slurry or liquid fraction of N flux.

```
0
```

tan_outhousing_liquid Annual N flux as TAN out of housing, slurry or liquid fraction of N flux.

```
0
```

n_outhousing_solid Annual N flux out of housing, manure fraction of N flux.

```
Out(n_outhousing);
```

tan_outhousing_solid Annual N flux as TAN out of housing, manure fraction of N flux.

```
Out(tan_outhousing);
```

Technical Parameters

er_housing 0.275
Emission rate for loose housing with liquid, solid manure system is assumed (for TAN 0.275 and Nsol 40%).

2.86 Livestock::RoughageConsuming::Housing::CFreeFactor

TODO

Inputs

free_correction_factor Factor to define free.

Outputs

c_free_factor_housing Free correction factor for NH3 housing emission.

```
if ( In(free_correction_factor) // 0 != 0 ) {
  writeLog({
    en => "You have entered an additional emission mitigation measure for a housing of the "
          . "category other roughage consuming of " . In(free_correction_factor)
          . "\%!\n",
    de => "Sie haben eine zusätzliche emissionsmindernde Massnahme für einen Stall der "
          . "Kategorie andere Raufutter Verzehrer von " . In(free_correction_factor)
          . "\% eingegeben!\n",
    fr => "Vous avez introduit une mesure supplémentaire limitant les émissions dans les "
          ."stabulations pour 'other roughage consuming' " . In(free_correction_factor)
          . "\%.\n"
    });
  return 1 - In(free_correction_factor) / 100;
}
else {
  return 1;
}
```

2.87 Livestock::RoughageConsuming::Housing::KGrazing

This process calculates the correction factor for the non proportional change of the housing emission according to the grazing hours per day. Source is Phillips et al. (1998) and Gilhespy et al. (2006) empirical estimation was done by Thomas Kupper.

Outputs

c_grazing The correction factor for the reduction of the housing emission depending on the number of grazing hours per day and the grazing days per year.

```
my $k_grazing = Tech(k_grazing_a) * exp(Tech(k_grazing_b) * Val(grazing_hours, ..::Grazing));
# scale with ratio grazing_days per year
($k_grazing - 1) * Val(grazing_days, ..::Grazing) / 365 + 1;
```

Technical Parameters

k_grazing_a 0.9989
Coefficient a of empirical estimation c = a * exp(b * grazing_hours).

k_grazing_b 0.0403
Coefficient a of empirical estimation c = a * exp(b * grazing_hours).

2.88 Livestock::RoughageConsuming::Grazing

This process calculates the annual NH3 emission from grazing goats, fattening sheep and milk-sheep based on the total N excreted on the pastures. The N excreted is calculated according to the time the animals spend on the pasture. It assumes that the excretions on the pasture are proportional to the time the animals are grazed.

2.88.1 References:

Bussink DW 1992. Ammonia volatilization from grassland receiving nitrogen fertilizer and rotationally grazed by dairy cattle. Fertilizer Research 33:257-265.

Bussink DW 1994. Relationship between ammonia volatilization and nitrogen fertilizer application rate, intake and excretion of herbage nitrogen by cattle on grazed swards. Fertilizer Research 38:111-121.

Jarvis SC, Hatch DJ, Lockyer DR 1989. Ammonia fluxes from grazed grassland: annual losses from cattle production systems and their relation to nitrogen inputs. Journal of Agricultural Science 113:99-108.

Peterson SO, Sommer SG, Aaes O, Soegaard K 1998. Ammonia losses from urine and dung of grazing cattle: effect of N intake. Atmospheric environment 32:295-300.

Ross CA, Jarvis SC 2001. Measurement of emission and deposition pattern of ammonia from urine in grass swards. Atmospheric environment 35:867-875.

Inputs

grazing_days Average grazing days per year.

grazing_hours Average grazing hours per day.

Outputs

grazing_hours Grazing hours per day.

```
In(grazing_hours);
```

grazing_days Grazing days per year.

```
In(grazing_days);
```

n_into_grazing Annual N excretion during grazing for roughage consuming animals.

```
Val(n_excretion,Excretion) *
In(grazing_days)  / 365 *
In(grazing_hours) /  24;
```

tan_into_grazing Annual solable N (TAN) excretion during grazing for roughage consuming animals.

```
Val(tan_excretion,Excretion) *
In(grazing_days)  / 365 *
In(grazing_hours) /  24;
```

ef_nh3_ngrazing Annual total NH3 emission from all grazing dairy cows.

```
Tech(er_roughage_consuming_grazing);
```

nh3_ngrazing Annual NH3 emission from roughage consuming animals from grazing.

```
Out(tan_into_grazing) * Out(ef_nh3_ngrazing);
```

n2_ngrazing Annual total N2 emission from all grazing roughage consuming animals..

```
Out(n_into_grazing) * Tech(er_n2_roughage_consuming_grazing);
```

no_ngrazing Annual total N2 emission from all grazing roughage consuming animals..

```
Out(n_into_grazing) * Tech(er_no_roughage_consuming_grazing);
```

n2o_ngrazing Annual total N2O emission from all grazing roughage consuming animals.

```
Out(n_into_grazing) * Tech(er_n2o_roughage_consuming_grazing);
```

n_remain_grazing Annual N input on pastures.

```
Out(n_into_grazing) -
Out(nh3_ngrazing) -
Out(n2_ngrazing) -
Out(no_ngrazing) -
Out(n2o_ngrazing);
```

tan_remain_grazing Annual N input on pastures.

```
Out(tan_into_grazing) -
Out(nh3_ngrazing) -
Out(n2_ngrazing) -
Out(no_ngrazing) -
Out(n2o_ngrazing);
```

Technical Parameters

er_roughage_consuming_grazing 0.125
Emission rate for the calculation of the annual NH3 emission during grazing of other roughage consuming animals ruminants. The emission rate is derived from Bussink et al. (1992, 1994), Jarvis et al. (1989), Peterson et al. (1998) and Ross and Jarvis (2001). (taking into account the generally low fertilization rate of Swiss pastures.)

er_n2_roughage_consuming_grazing 0.0
Emission rate for manure application. Not considerd relevant

er_no_roughage_consuming_grazing 0.0055
Emission rate for manure application. Stehfest, Bouwman 2006

er_n2o_roughage_consuming_grazing 0.01
Emission rate for manure application. ICCP 2006: v4_11Ch_11; Tab11.1

2.89 Livestock::RoughageConsuming::NxOx

TODO!

Outputs

n2_nsolid Annual N2 emission from other animals housing and grazing.

```
Val(n_into_housing, Housing) * Tech(er_n2_nsolid);
```

no_nsolid Annual NO emission from other animals housing and grazing.

```
Val(n_into_housing, Housing) * Tech(er_no_nsolid);
```

n2o_nsolid Annual N2O emission from other animals housing and grazing.

```
Val(n_into_housing, Housing) * Tech(er_n2o_nsolid);
```

Technical Parameters

er_n2_nsolid 0.05
Emission rate for N2 based on Ntot

er_no_nsolid 0.01
Emission rate for N2 based on Ntot

er_n2o_nsolid 0.01
Emission rate for N2 based on Ntot

3 Stage Storage

3.1 Storage

This process calculates the NH3 emission from slurry storage, considering both slurry from slurry based systems and liquid from liquid/solid systems. The surface to volume ration (measure for the emitting surface), the cover type and artificial slurry aeration are accounted for via correction factors. Calculations are performed independently for slurry and liquid from liquid/solid systems with the same procedure.

3.1.1 References:

De Bode MJC, 1990. Vergleich der Ammoniakemissionen aus verschiedenen Flüssigmistlager-systemen. In: Ammoniak in der Umwelt. Hrsg.: KTBL und VDI, Münster, 34:1-13.

Outputs

has_liquid_storage True (1) if a Liquid Storage (Volume) is present.

```
my $volume = Sum(volume, Storage::Slurry) // 0;
if ( $volume > 0){
  return 1;
}
else {
  if( Val(n_out_livestock_liquid, ::Livestock) > 0 ) {
    writeLog(
        {
          en => "No storage for slurry defined although slurry is produced!\n",
          de => "Es ist kein Güllelager eingegeben, obwohl Gülle anfällt!\n",
          fr => "Aucun stock de lisier n'est mentionné, alors qu'il y a production de lisier!\n"
        }
    );
  }
  return 0;
}
```

mineralization Annual TAN mineralized from not-TAN fraction in liquid storage.

```
(
  Val(n_out_livestock_liquid, ::Livestock) P-
  Val(tan_out_livestock_liquid, ::Livestock)
) P*
scale(
  Val(has_pigs, ::Livestock) P+ Val(has_cattle, ::Livestock),
  Tech(mineralizationrate_liquid)
);
```

n_into_storage_liquid Annual N flux into liquid storage.

```
Val(n_out_livestock_liquid, ::Livestock);
```

n_into_storage_solid Annual N flux into solid storage.

```
Val(n_out_livestock_solid, ::Livestock) P*
(
  Val(share_into_storage_solid_no_poultry, Storage::SolidManure::Solid) P+
  Val(share_into_storage_solid_poultry, Storage::SolidManure::Poultry)
);
```

n_directly_applied_solid Annual N flux directly applied.

```
Val(n_out_livestock_solid, ::Livestock) P-
Out(n_into_storage_solid);
```

n_into_storage Annual N flux into liquid storage.

```
Out(n_into_storage_liquid) P+
Out(n_into_storage_solid);
```

tan_into_storage_liquid Annual TAN flux into liquid storage.

```
Val(tan_out_livestock_liquid, ::Livestock);
```

tan_into_storage_solid Annual TAN flux into solid storage.

```
Val(tan_out_livestock_solid, ::Livestock) P*
(
  Val(share_into_storage_solid_no_poultry, Storage::SolidManure::Solid) P+
  Val(share_into_storage_solid_poultry, Storage::SolidManure::Poultry)
);
```

tan_directly_applied_solid Annual TAN flux directly applied.

```
Val(tan_out_livestock_solid, ::Livestock) P-
Out(tan_into_storage_solid);
```

tan_into_storage Annual TAN flux into liquid storage.

```
Out(tan_into_storage_liquid) P+
Out(tan_into_storage_solid);
```

tan_into_storage_liquid_pigs Annual TAN flux into liquid storage.

```
multiplyPairwise(
  Val(has_pigs, ::Livestock),
  Out(tan_into_storage_liquid)
);
```

tan_into_storage_liquid_cattle Annual TAN flux into liquid storage.

```
multiplyPairwise(
  Val(has_cattle, ::Livestock),
  Out(tan_into_storage_liquid)
);
```

maxlimit_of_nh3_nstorage_liquid_pigs Upper limit of the annual NH3 emission from liquid storage of pig slurry.

```
multiplyPairwise(
  Val(has_pigs, ::Livestock),
  Val(tan_out_livestock_liquid, ::Livestock) P+
  Out(mineralization) P-
  Val(n2o_nliquid_housing_and_storage, ::Livestock) P-
  Val(no_nliquid_housing_and_storage, ::Livestock) P-
  Val(n2_nliquid_housing_and_storage, ::Livestock)
);
```

nh3_nstorage_liquid_pigs Annual NH3 emission from liquid storage of pig slurry.

```
my $nh3_loss_pigs = Sum(nh3_ntank_liquid_pigs, Storage::Slurry);
given ( scalar($nh3_loss_pigs) ) {
  when $_ eq 0 {
    scale(Out(tan_into_storage_liquid_pigs), 0);
  }
  when $_ > scalar(Out(maxlimit_of_nh3_nstorage_liquid_pigs)) {
    writeLog(
        {
            en => "The size of the slurry store induces an NH3 loss which is larger than the TAN flow into th
            de => "Die Grösse des Güllelagers hat zur Folge, dass die NH3 Verluste grösser sind als der TAN F
            fr => "La dimension de la fosse à lisier induit une perte de NH3 plus élevée que le flux de TAN d
        }
    );
    Out(maxlimit_of_nh3_nstorage_liquid_pigs);
  }
  default {
    scale(
      Out(tan_into_storage_liquid_pigs),
```

```
      $nh3_loss_pigs /
      scalar(Out(tan_into_storage_liquid_pigs))
    );
  }
}
```

maxlimit_of_nh3_nstorage_liquid_cattle Upper limit of the annual NH3 emission from liquid storage of pig slurry.

```
multiplyPairwise(
  Val(has_cattle, ::Livestock),
  Val(tan_out_livestock_liquid, ::Livestock) P+
  Out(mineralization) P-
  Val(n2o_nliquid_housing_and_storage, ::Livestock) P-
  Val(no_nliquid_housing_and_storage, ::Livestock) P-
  Val(n2_nliquid_housing_and_storage, ::Livestock)
);
```

nh3_nstorage_liquid_cattle Annual NH3 emission from liquid storage of cattle slurry.

```
my $nh3_loss_cattle = Sum(nh3_ntank_liquid_cattle, Storage::Slurry);
given ( scalar($nh3_loss_cattle) ) {
  when $_ eq 0 {
    scale(Out(tan_into_storage_liquid_cattle), 0);
  }
  when $_ > scalar(Out(maxlimit_of_nh3_nstorage_liquid_cattle)) {
    writeLog(
        {
            en => "The size of the slurry store induces an NH3 loss which is larger than the TAN flow into th
            de => "Die Grösse des Güllelagers hat zur Folge, dass die NH3 Verluste grösser sind als der TAN F
            fr => "La dimension de la fosse à lisier induit une perte de NH3 plus élevée que le flux de TAN d
        }
    );
    Out(maxlimit_of_nh3_nstorage_liquid_cattle);
  }
  default {
    scale(
      Out(tan_into_storage_liquid_cattle),
      $nh3_loss_cattle /
      scalar(Out(tan_into_storage_liquid_cattle))
    );
  }
}
```

nh3_nstorage_liquid Annual NH3 emission from storage.

```
Out(nh3_nstorage_liquid_pigs) P+
Out(nh3_nstorage_liquid_cattle);
```

nh3_nstorage_solid Annual NH3 emission from storage.

```
Out(tan_into_storage_solid) P*
(
  Val(er_nh3_nstorage_solid_no_poultry, Storage::SolidManure::Solid) P+
  Val(er_nh3_nstorage_solid_poultry, Storage::SolidManure::Poultry)
);
```

nh3_nstorage Annual NH3 emission from storage.

```
Out(nh3_nstorage_liquid) P+
Out(nh3_nstorage_solid);
```

immobilization Annual TAN immobilized from TAN fraction in solid manure storage.

```
(
  Out(tan_into_storage_solid) P-
  Out(nh3_nstorage_solid)
) P*
(
  Val(immobilization_rate_no_poultry, Storage::SolidManure::Solid) P+
```

```
  Val(immobilization_rate_poultry, Storage::SolidManure::Poultry)
);
```

n_into_application_liquid Annual N flux out of storage for application.

```
Val(n_out_livestock_liquid, ::Livestock) P-
Out(nh3_nstorage_liquid) P-
Val(n2o_nliquid_housing_and_storage, ::Livestock) P-
Val(no_nliquid_housing_and_storage, ::Livestock) P-
Val(n2_nliquid_housing_and_storage, ::Livestock);
```

tan_into_application_liquid Annual N flux as TAN out of storage for application.

```
Val(tan_out_livestock_liquid, ::Livestock) P-
Out(nh3_nstorage_liquid) P-
Val(n2o_nliquid_housing_and_storage, ::Livestock) P-
Val(no_nliquid_housing_and_storage, ::Livestock) P-
Val(n2_nliquid_housing_and_storage, ::Livestock) P+
Out(mineralization);
```

n_into_application_solid Annual N flux out of storage for manure application.

```
Val(n_out_livestock_solid, ::Livestock) P-
Val(n2_nsolid_housing_and_storage, ::Livestock) P-
Val(no_nsolid_housing_and_storage, ::Livestock) P-
Val(n2o_nsolid_housing_and_storage, ::Livestock) P-
Out(nh3_nstorage_solid);
```

tan_into_application_solid Annual TAN flux out of storage for manure application.

```
Val(tan_out_livestock_solid, ::Livestock) P-
Val(n2_nsolid_housing_and_storage, ::Livestock) P-
Val(no_nsolid_housing_and_storage, ::Livestock) P-
Val(n2o_nsolid_housing_and_storage, ::Livestock) P-
Out(nh3_nstorage_solid) P-
Out(immobilization);
```

n_into_application Annual N flux out of storage for application.

```
Out(n_into_application_liquid) P+
Out(n_into_application_solid) ;
```

tan_into_application Annual TAN flux out of storage for application.

```
Out(tan_into_application_liquid) P+
Out(tan_into_application_solid);
```

Technical Parameters

mineralizationrate_liquid 0.1

A netto mineralization of 10% from Norg to NSol/TAN is assuemd, according to the GAS_EM Model

3.2 Storage::SolidManure::Poultry

This process calculates the annual NH3 emission from poultry manure storage, considering a mean emission rate on TAN flux in storage.

3.2.1 References

European Agricultural Gaseous Emissions Inventory Researchers Network - EAGER workshop, January 2008.

Inputs

share_applied_direct_poultry_manure Share of poultry manure applied to land without storage.

share_covered_basin Share of droppings or mist from poultry stored in covered basin.

free_correction_factor Factor to define free ?

Outputs

c_covered_basin Correction factor for storage droppings or mist in coverd basin.

```
1 - ( Tech(c_droppings_mist_covered_basin) * In(share_covered_basin)/100 );
```

c_free_factor_storage_poultrymanure Free reduction of the Emission rate for the Yard.

```
if(In(free_correction_factor)//0 != 0) {
    writeLog({en=>"You have entered an additional emission mitigation measure for a storage of poultry manure
                 . In(free_correction_factor)
                 . " \%!\n",
              de=>"Sie haben eine zusätzliche emissionsmindernde Massnahme für das Geflügelmistlager von "
                 . In(free_correction_factor)
                 . "\% eingegeben!\n",
              fr=> "Vous avez introduit une mesure supplémentaire limitant les émissions du stock "
                  . "de fumier de volaille de " . In(free_correction_factor) . "\%.\n"
             });
    return 1 - In(free_correction_factor)/100;

} else {
  return 1;
}
```

n_check Check shares of directly applied and covered storage of poultry manure

```
if (  (In(share_applied_direct_poultry_manure) + In(share_covered_basin)) > 100  ) {
writeLog({en=>"The sum of Share of poultry manure applied to land without storage and Share of poultry manure
          de=>"Die Summe von Anteil von direkt ohne Lagerung ausgebrachtem Geflügelmist und Anteil von gedeck
          fr=>"La somme de Part des fientes ou du fumier de volaille épandu directement sans stockage et de P
         });
}
return;
```

share_into_storage_solid_poultry Annual TAN flux into solid storage from pigs.

```
scale(
  Val(has_poultry, ::Livestock),
  (1 - In(share_applied_direct_poultry_manure) / 100)
);
```

er_nh3_nstorage_solid_poultry Annual NH3 emission from poultry manure storage.

```
scale(
  scale(
    Val(has_poultry_LGO, ::Livestock),
    Tech(er_layers_growers_other_poultry)
```

```
  ) P+
  scale(
    Val(has_poultry_TB, ::Livestock),
    Tech(er_turkeys_broilers)
  ),
  Out(c_covered_basin) *
  Out(c_free_factor_storage_poultrymanure)
);
```

immobilization_rate_poultry Annual TAN immobilized from TAN fraction in solid manure storage.

```
scale(
  Val(has_poultry, ::Livestock),
  Tech(immobilizationrate_poultry)
);
```

Technical Parameters

er_layers_growers_other_poultry 0.25
Emission rate for layers, growers and other poultry for manure (deep pit, deep litter) and droppings (manure belt)(based on EAGER workshop, January 2008: 15% Ntot, converted using Nsol 60% and emission factor of 25%.

er_turkeys_broilers 0.1
Emission rate for manure of broilers and turkeys based on EAGER workshop, January 2008: 6% Ntot, converted using Nsol 60% and emission factor of 10%.

c_droppings_mist_covered_basin 0.75
Reduction of emission rate for the droppings or mist stored in covered basin for poultry.

immobilizationrate_poultry 0
No Immobilization is taken into account.

3.3 Storage::SolidManure::Solid

This process calculates the annual NH3 emission from solid manure storage, considering a mean emission rate on TAN flux in solid storage.

Inputs

share_applied_direct_cattle_other_manure Share of cattles, equides and small ruminants manure applied to land without storage.

share_covered_basin_cattle_manure Share of droppings or mist from cattle stored in covered basin.

free_correction_factor_cattle_manure Factor to define free ?

share_applied_direct_pig_manure Share of pig manure applied to land without storage.

share_covered_basin_pig_manure Share of droppings or mist from pigs stored in covered basin.

free_correction_factor_pig_manure Factor to define free ?

Outputs

n_check_cattle Check shares of directly applied and covered storage of cattle manure

```
if (  (In(share_applied_direct_cattle_other_manure) + In(share_covered_basin_cattle_manure)) > 100  ) {
writeLog({en=>"The sum of share of cattle manure applied to land without storage and share of cattle manure c
          de=>"Die Summe von Anteil von direkt ohne Lagerung ausgebrachtem Mist von Rindvieh und Anteil von g
          fr=>"La somme de part du fumier de bovins épandu directement sans stockage et de part du fumier de
         });
}
return;
```

n_check_pigs Check shares of directly applied and covered storage of pig manure

```
if (  (In(share_applied_direct_pig_manure) + In(share_covered_basin_pig_manure)) > 100  ) {
writeLog({en=>"The sum of share of cattle manure applied to land without storage and share of cattle manure c
          de=>"Die Summe von Anteil von direkt ohne Lagerung ausgebrachtem Schweinemist und Anteil von gedeck
          fr=>"La somme de part du fumier de porcs épandu directement sans stockage et de part du fumier de p
         });
}
return;
```

c_free_factor_storage_solidmanure_cattle Free reduction of the Emission rate for the Yard Storage, cattle manure.

```
if(In(free_correction_factor_cattle_manure)//0 != 0) {
    writeLog({en=>"You have entered an additional emission mitigation measure for a storage of cattle solid m
                 . In(free_correction_factor_cattle_manure)
                 . "\%!\n",
              de=>"Sie haben eine zusätzliche emissionsmindernde Massnahme für das Mistlager der Rinder von"
                 . In(free_correction_factor_cattle_manure)
                 . "\% eingegeben!\n",
              fr=>"Vous avez introduit une mesure supplémentaire limitant les émissions du "
                 . "stock de fumier des porcs de " . In(free_correction_factor_cattle_manure)
                 . "\%.\n"
              });
        return 1 - In(free_correction_factor_cattle_manure)/100;

} else {
  return 1;
}
```

c_free_factor_storage_solidmanure_pig Free reduction of the Emission rate for Storage Pig manure.

```
if(In(free_correction_factor_pig_manure)//0 != 0) {
    writeLog({en=>"You have entered an additional emission mitigation measure for a storage of pigs solid man
                  . In(free_correction_factor_cattle_manure)
                  . "\%!\n",
              de=>"Sie haben eine zusätzliche emissionsmindernde Massnahme für das Mistlager der Schweine von
                . In(free_correction_factor_pig_manure)
                  . "\% eingegeben!\n",
              fr=>"'Vous avez introduit une mesure supplémentaire limitant les émissions du "
                  . "stock de fumier des bovins de" . In(free_correction_factor_pig_manure)
                  . "\%.\n"
             });
    return 1 - In(free_correction_factor_pig_manure)/100;

} else {
  return 1;
}
```

c_covered_basin_cattle Correction factor for manure of cattle stored in coverd basin.

```
1 - ( Tech(c_covered_basin_cattle_manure) * In(share_covered_basin_cattle_manure)/100 );
```

c_covered_basin_pig Correction factor for manure of pigs stored in coverd basin.

```
1 - ( Tech(c_covered_basin_pig_manure) * In(share_covered_basin_pig_manure)/100 );
```

share_into_storage_solid_no_poultry Annual TAN flux into solid storage from pigs.

```
scale(
  Val(has_cattle, ::Livestock) P+
  Val(has_others, ::Livestock),
  (1 - In(share_applied_direct_cattle_other_manure) / 100)
) P+
scale(
  Val(has_pigs, ::Livestock),
  (1 - In(share_applied_direct_pig_manure) / 100)
);
```

er_nh3_nstorage_solid_no_poultry Annual NH3 emission from solid storage.

```
scale(
  Val(has_cattle, ::Livestock) P+
  Val(has_others, ::Livestock),
  Tech(er_tan_cattle_other) *
  Out(c_covered_basin_cattle) *
  Out(c_free_factor_storage_solidmanure_cattle)
) P+
scale(
  Val(has_pigs, ::Livestock),
  Tech(er_tan_pigs) *
  Out(c_covered_basin_pig) *
  Out(c_free_factor_storage_solidmanure_pig)
);
```

immobilization_rate_no_poultry Annual TAN immobilized from TAN fraction in solid manure storage.

```
scale(
  Val(has_no_poultry, ::Livestock),
  Tech(immobilizationrate_solid)
);
```

Technical Parameters

er_tan_pigs 0.5
The value has been derived from the Eager workshop, January 2008: (additional explanation following)

er_tan_cattle_other 0.3
: The value has been derived from the Eager workshop, January 2008: (additional explanation following)

immobilizationrate_solid 0.4
: A netto immobilization of 40% from NSol/TAN to Norg is assuemd, according to the GAS_EM Model

c_covered_basin_cattle_manure 0.5
: Reduction of emission rate for manure of cattle stored in covered basin Chadwick (2005); Sagoo et al. (2006) (Defra WA 716, 1999).

c_covered_basin_pig_manure 0.75
: Reduction of emission rate for manure of pigs stored in covered basin, Sagoo et al. (2006, 2007).

3.4 Storage::Slurry

This Process calculates the annual NH3 emission from a single liquid manuare storage, considering a specific emission factor.

3.4.1 References

De Bode MJC, 1990. Vergleich der Ammoniakemissionen aus verschiedenen Flüssigmistlagersystemen. In: Ammoniak in der Umwelt. Hrsg.: KTBL und VDI, Münster, 34:1-13. Menzi H, Frick R, Kaufmann R, 1997a. Ammoniak-Emissionen in der Schweiz: Ausmass und technische Beurteilung des Reduktionspotentials. Eidgenössische Forschungsanstalt für Agrarökologie und Landbau, Zürich-Reckenholz. 107pp. Sommer SG, Christensen BT, Nielsen NE, Schjorring JK, 1993. Ammonia volatilization during storage of cattle and pig slurry - effect of surface cover. Journal of Agricultural Science 121:63-71.

Inputs

volume Volume of slurry store.

depth Depth of slurry store.

mixing_frequency Frequency of mixing of slurry store.

Outputs

c_mixing Correction factor for number of mixing frequency in storage, accoording to selected levels.

```
my $mixing = In(mixing_frequency) // '7_to_12_times_per_year';
return $TE->{'c_mixing_' . $mixing};
```

depth Depth of slurry storage.

```
In(depth)
```

volume Volume of slurry storage.

```
In(volume)
```

surface_area Surface area of slurry storage.

```
if ( (not defined In(depth)) or Out(depth) <= 0 ) {
    return 0;
} else {
    return Out(volume) / Out(depth);
}
```

nh3_ntank_liquid_pigs Annual NH3 emission from slurry storage.

```
Val(er_nh3_storage_liquid_pigs, Slurry::EFLiquid) *
Out(surface_area) *
Out(c_mixing) *
Val(c_free_factor_storage_slurry, Slurry::EFLiquid) ;
```

nh3_ntank_liquid_cattle Annual NH3 emission from slurry storage.

```
Val(er_nh3_storage_liquid_cattle, Slurry::EFLiquid) *
Out(surface_area) *
Out(c_mixing) *
Val(c_free_factor_storage_slurry, Slurry::EFLiquid) ;
```

Technical Parameters

c_mixing_at_most_2_times_per_year 0.9
Correction for mixingfrequency in slurry storage. Based on DeBode(1990), Sommer et al.(1993), Menzi et al. (1997a)

c_mixing_1_to_2_times_per_year 0.9
Correction for mixingfrequency in slurry storage. Based on DeBode(1990), Sommer et al.(1993), Menzi et al. (1997a)

c_mixing_3_to_6_times_per_year 0.95
Correction for mixingfrequency in slurry storage. Based on DeBode(1990), Sommer et al.(1993), Menzi et al. (1997a)

c_mixing_7_to_12_times_per_year 1
Correction for mixingfrequency in slurry storage. Default or Basis value

c_mixing_13_to_20_times_per_year 1.1
Correction for mixingfrequency in slurry storage. Empirical Estimation Reidy/Menzi

c_mixing_21_to_30_times_per_year 1.2
Correction for mixingfrequency in slurry storage. Empirical Estimation Reidy/Menzi

c_mixing_more_than_30_times_per_year 1.3
Correction for mixingfrequency in slurry storage.

3.5 Storage::Slurry::EFLiquid

3.5.1 References

UNECE 2007. Guidance document on control techniques for preventing and abating emissions of ammonia. ECE/EB.AIR/WG.5/2007/13.

De Bode MJC, 1990. Vergleich der Ammoniakemissionen aus verschiedenen Flüssigmistlager-systemen. In: Ammoniak in der Umwelt. Hrsg.: KTBL und VDI, Münster(D), 34:1-13.

Sommer SG, Christensen BT, Nielsen NE, Schjorring JK, 1993. Ammonia volatilization during storage of cattle and pig slurry - effect of surface cover. Journal of Agricultural Science 121:63-71.

Inputs

cover_type Cover type of liquid storage.

contains_cattle_manure Describes if the specific storage contains cattle manure.

contains_pig_manure Describes if the specific storage contains pig manure.

free_correction_factor Factor to define free ?

Outputs

er_nh3_storage_liquid_pigs Scaled emission factor of a specific liquid storage for pig slurry.

```
if (not defined In(cover_type)) {
    writeLog({
      en => 'FIX: Invalid values for "cover_type" (' . In(cover_type) . ')' . "\n",
      de => 'FIX: Ungültige Eingabe für "cover_type" (' . In(cover_type) . ')' . "\n",
      fr => 'FIX: Entrée non valable pour "cover_type" (' . In(cover_type) . ')' . "\n"
    });
   return 0;
}
my $er_pigs = $TE->{'ef_pig_'.In(cover_type)};
# scale er pigs
if ( not defined In(contains_pig_manure) ) {
  writeLog({
    en => 'Invalid values for "Contains pigs slurry" (' . In(contains_pig_manure) . ')' . "\n",
    de => 'Ungültige Eingabe für "Enthält Schweinegülle" (' . In(contains_pig_manure) . ')' . "\n",
    fr => 'Entrée non valable pour "Contient du lisier de porc" (' . In(contains_pig_manure) . ')' . "\n"
  });
  return Val(n_out_livestock_liquid_pigs_share, ::Livestock) * $er_pigs;
} elsif ( not defined In(contains_cattle_manure) ) {
  return Val(n_out_livestock_liquid_pigs_share, ::Livestock) * $er_pigs;
} elsif ( lc In(contains_pig_manure) eq 'no' ) {
  return 0;
} elsif ( lc In(contains_pig_manure) eq 'yes' and lc In(contains_cattle_manure) eq 'no' ) {
  return $er_pigs;
} else {
  return Val(n_out_livestock_liquid_pigs_share, ::Livestock) * $er_pigs;
}
```

er_nh3_storage_liquid_cattle Scaled emission factor of a specific liquid storage for cattle slurry.

```
if (not defined In(cover_type)) {
   return 0;
}
my $er_cattle = $TE->{'ef_cattle_'.In(cover_type)};
if ( not defined In(contains_cattle_manure) ) {
  writeLog({
    en => 'Invalid values for "Contains cattle slurry" (' . In(contains_cattle_manure) . ')' . "\n",
    de => 'Ungültige Eingabe für "Enthält Rindergülle" (' . In(contains_cattle_manure) . ')' . "\n",
    fr => 'Entrée non valable pour "Contient du lisier de bovin" (' . In(contains_cattle_manure) . ')' . "\n"
  });
```

```
  return (1 - Val(n_out_livestock_liquid_pigs_share, ::Livestock)) * $er_cattle;
} elsif ( not defined In(contains_pig_manure) ) {
  return (1 - Val(n_out_livestock_liquid_pigs_share, ::Livestock)) * $er_cattle;
} elsif ( lc In(contains_cattle_manure) eq 'no' ) {
  return 0;
} elsif ( lc In(contains_cattle_manure) eq 'yes' and lc In(contains_pig_manure) eq 'no' ) {
  return $er_cattle;
} else {
  return (1 - Val(n_out_livestock_liquid_pigs_share, ::Livestock)) * $er_cattle;
}
```

c_free_factor_storage_slurry Free reduction of the Emission rate for the Yard.

```
if(In(free_correction_factor)//0 != 0) {
    writeLog({en=>"You have entered an additional emission mitigation measure for a storage of slurry of "
                  . In(free_correction_factor)
                  . "\%!\n",
              de=>"Sie haben eine zusätzliche emissionsmindernde Massnahme für ein Güllelager von "
                  . In(free_correction_factor)
                  . "\% eingegeben!\n",
              fr=>"Vous avez introduit une mesure supplémentaire limitant les émissions "
                  . "du stock de lisier de " . In(free_correction_factor) . "\%.\n" });
          return 1 - In(free_correction_factor)/100;

} else {
  return 1;
}
```

Technical Parameters

ef_cattle_uncovered 2.19
: The emission factor for uncovered storage is based on experiments of de Bode (1990) and Sommer et al. (1993) measuring emissions of 2.5 to 6.9 g N m-2 day-1 for cattle slurry, for the emission of the none coverd a mean of the higher values is assumed. -> Assumption: 6.0 gN m-2 day-1 resp. 2.19 kg N /m2 /yr according to the results of the decision of the session of 10 April 208 (participants: C. Bonjour, C. Leuenbergern, M. Raaflaub, H. Menzi, T. Kupper).

ef_cattle_solid_cover 0.219
: Emission factor for solid covered storage based on ef_cattle_uncovered with a reduction of 90%. UNECE (2007) p 13 does suggest a reduction of 80%. Since covers of storages are more tight in Switzerland a reduction of 90% was choosen.

ef_cattle_tent 0.876
: Emission factor for tent covered storage (ef_cattle_uncovered with a reduction of 60%) differs to the UNECE (2007) p.13 reference (ef_cattle_uncovered with a reduction of 80% after UNECE (2007))based on mutual agreement of AGRAMMON participants that newer studies showed that tent covered storage emit more ammonia then assumed by UNECE.

ef_cattle_floating_cover 0.438
: Emission factor for floating covered storage (sheeting may be a type of plastic, canvas or other suitable material) (ef_cattle_uncovered with a reduction of 80%) differs to the UNECE (2007) p.13 referrence (ef_cattle_uncovered with a reduction of 60% after UNECE (2007))based on mutual agreement of AGRAMMON participants that newer studies showed that floating covered storage emit less ammonia then assumed by UNECE.

ef_cattle_perforated_cover 1.314
: Emission factor for perforated_cover storage based on ef_cattle_uncovered with a reduction of 40% after UNECE (2007) p 13.

ef_cattle_natural_crust 1.314
: Emission factor for a natural crust covered storage based on ef_cattle_uncovered with a

reduction of 40% after UNECE (2007) p 13.

ef_pig_uncovered 2.92
The Emission factor for uncovered storage is based on experiments of de Bode (1990) and Sommer et al. (1993) measuring emissions of 2.5 to 6.9 g N m-2 day-1 for cattle slurry, for the emission of the none coverd a mean of the higher values is assumed. Assumption: 8.0 gN m-2 day-1 resp. 2.92 kgN m-2 /yr according to the report "Abklärungen zur Klasierung von Stallsystemen und Hofdüngerlagern bezüglich der Ammoniak-Emissionen" and the decision of the session of 10 April 208 (participants: C. Bonjour, C. Leuenbergern, M. Raaflaub, H. Menzi, T. Kupper).

ef_pig_solid_cover 0.292
Emission factor for solid coverd storage based on ef_pig_uncovered with a reduction of 90%. UNECE (2007) p 13 does suggest a reduction of 80%.Since covers of storages are more tight in Switzerland a reduction of 90% was choosen.

ef_pig_tent 1.168
Emission factor for tent covered storage (ef_pig_uncovered with a reduction of 60%) differs to the UNECE (2007) p.13 referrence (ef_pig_uncovered with a reduction of 80% after UNECE (2007))based on mutual agreement of AGRAMMON participants that newer studies showed that tent covered storage emit more ammonia then assumed by UNECE.

ef_pig_floating_cover 0.584
Emission factor for floating covered storage (sheeting may be a type of plastic, canvas or other suitable material) (ef_pig_uncovered with a reduction of 80%) differs to the UNECE (2007) p.13 referrence (ef_pig_uncovered with a reduction of 60% after UNECE (2007))based on mutual agreement of AGRAMMON participants that newer studies showed that floating covered storage emit less ammonia then assumed by UNECE.

ef_pig_perforated_cover 1.752
Emission factor for perforated_cover storage based on ef_pig_uncovered with a reduction of 40% after UNECE (2007) p 13.

ef_pig_natural_crust 1.752
Emission factor for a natural crust covered storage (e.g. chopped straw, peat, bark, LECA balls, ect.)based on ef_pig_uncovered with a reduction of 40% after UNECE (2007) p 13.

4 Stage Application

4.1 Application

This process summarizes the contribution of the individual manure systems to the total NH3 emission from manure application.

4.1.1 Differences to DYNAMO

The categories ”Soil absorptive” and ”application before rain” are omitted since the practice is unknown and experimental results are not available (according to the decision of the steering group from 02/07/2007).

The distinction between the categories incorporation of solid manure by chisel plough or plough are omitted since the difference is unclear (according to the decision of the steering group from 02/07/2007).

The category ”rapid incorporation” is replaced by ”application manure” since slurry is hardly incorporated in Switzerland. The entire category is adapted to UNECE (2007) including new categories.

Outputs

n_into_application_liquid Annual N flux into liquid manure application.

```
Val(n_into_application_liquid, Storage);
```

n_into_application_solid Annual N flux into solid manure application.

```
Val(n_into_application_solid, Storage);
```

n_into_application Annual N flux into manure application.

```
Out(n_into_application_liquid) P+
Out(n_into_application_solid);
```

tan_into_application_liquid Annual TAN flux into liquid manure application.

```
Val(tan_into_application_liquid, Storage);
```

tan_into_application_solid Annual TAN flux into solid manure the application.

```
Val(tan_into_application_solid, Storage);
```

tan_into_application Annual TAN flux into manure the application.

```
Out(tan_into_application_liquid) P+
Out(tan_into_application_solid);
```

nh3_napplication_solid Annual NH3 emission from solid manure application.

```
Out(tan_into_application_solid) P*
(
  Val(er_nh3_napplication_solid_no_poultry, Application::SolidManure::Solid) P+
  Val(er_nh3_napplication_solid_poultry, Application::SolidManure::Poultry)
);
```

nh3_napplication_liquid Annual NH3 emission from liquid manure application.

```
Val(nh3_napplication_liquid, Application::Slurry);
```

nh3_napplication Annual NH3 emission from manure application.

```
Out(nh3_napplication_solid) P+
Out(nh3_napplication_liquid);
```

n2_napplication_liquid Annual N2 emission from liquid manure application.

```
Out(n_into_application_liquid) P*
Val(er_n2_napplication_liquid, Application::Slurry);
```

n2_napplication_solid Annual N2 emission from solid manure application.

```
Out(n_into_application_solid) P*
(
  Val(er_n2_napplication_solid_no_poultry, Application::SolidManure::Solid) P+
  Val(er_n2_napplication_solid_poultry, Application::SolidManure::Poultry)
);
```

n2_napplication Annual N2 emission from manure application.

```
Out(n2_napplication_liquid) P+
Out(n2_napplication_solid);
```

no_napplication_liquid Annual NO emission from liquid manure application.

```
Out(n_into_application_liquid) P*
Val(er_no_napplication_liquid, Application::Slurry);
```

no_napplication_solid Annual NO emission from solid manure application.

```
Out(n_into_application_solid) P*
(
  Val(er_no_napplication_solid_no_poultry, Application::SolidManure::Solid) P+
  Val(er_no_napplication_solid_poultry, Application::SolidManure::Poultry)
);
```

no_napplication Annual NO emission from manure application.

```
Out(no_napplication_solid) P+
Out(no_napplication_liquid);
```

n2o_napplication_liquid Annual N2O emission from liquid manure application.

```
Out(n_into_application_liquid) P*
Val(er_n2o_napplication_liquid, Application::Slurry);
```

n2o_napplication_solid Annual N2O emission from solid manure application.

```
Out(n_into_application_solid) P*
(
  Val(er_n2o_napplication_solid_no_poultry, Application::SolidManure::Solid) P+
  Val(er_n2o_napplication_solid_poultry, Application::SolidManure::Poultry)
);
```

n2o_napplication Annual N2O emission from manure application.

```
Out(n2o_napplication_solid) P+
Out(n2o_napplication_liquid);
```

n_remain_application_liquid Annual N flux out of liquid manure application.

```
Out(n_into_application_liquid) P-
Out(nh3_napplication_liquid) P-
Out(n2_napplication_liquid)  P-
Out(no_napplication_liquid)  P-
Out(n2o_napplication_liquid);
```

n_remain_application_solid Annual N flux out of solid manure application.

```
Out(n_into_application_solid) P-
Out(nh3_napplication_solid) P-
Out(n2_napplication_solid)  P-
Out(no_napplication_solid)  P-
Out(n2o_napplication_solid);
```

n_remain_application Annual N flux out of manure application.

```
Out(n_remain_application_liquid)  P+
Out(n_remain_application_solid);
```

tan_remain_application_liquid Annual TAN flux out of liquid manure application.

```
Out(tan_into_application_liquid) P-
Out(nh3_napplication_liquid) P-
Out(n2_napplication_liquid)  P-
Out(no_napplication_liquid)  P-
Out(n2o_napplication_liquid);
```

tan_remain_application_solid Annual TAN flux out of solid manure application.

```
Out(tan_into_application_solid) P-
Out(nh3_napplication_solid) P-
Out(n2_napplication_solid)  P-
Out(no_napplication_solid)  P-
Out(n2o_napplication_solid);
```

tan_remain_application Annual TAN flux out of manure application.

```
Out(tan_remain_application_liquid)  P+
Out(tan_remain_application_solid);
```

4.2 Application::Slurry

This process computes the annual NH3 emission from slurry application. The standard emission factor for slurry application is corrected according to the TAN content and the application rate, the application technology, the crops to which the manure is applied, soft measures applied during application and the application season.

Since slurry is hardly incorporated in Switzerland, no correction for incorporeation was made for slurry application.

4.2.1 References:

Flisch R, Sinaj S, Charles R, Richner W 2009. Grundlagen für die die Düngung im Acker- und Futterbau. Agrarforschung 16(2).

Frick R, Menzi H, Katz P 1996. Ammoniakverluste nach der Hofdüngeranwendung. FAT-Bericht Nr. 486.

Katz P E 1996. Dissertation: Ammoniakemissionen nach der Gülleanwendung auf Grünland. Diss. ETH Nr. 11382. Dissertation. Eidgenössische Technische Hochschule Zürich.

Menzi H, Frick R, Kaufmann R 1997a. Ammoniak-Emissionen in der Schweiz: Ausmass und technische Beurteilung des Reduktionspotentials. Eidgenössische Forschungsanstalt für Agrarökologie und Landbau, Zürich-Reckenholz. 107pp.

Menzi H, Katz, PE, Fahrni M, Neftel A, Frick R 1998. A simple empirical model based on regression analysis to estimate ammonia emissions after manure application. Atmospheric Environment 32:301-307.

Sogaard H T, Sommer S G, Hutchings N J, Huijsmans J F M, Bussink D W, Nicholson F 2002. Ammonia volatilization from field-applied animal slurry - the ALFAM model. Atmospheric Environment 36: 3309-3319.

Sommer S G 2001b. Effect of coposting on nutrient loss and nitrogen availability of cattle deep litter. European Journal of Agronomy 14: 123-133.

Outputs

nh3_napplication_liquid Total annual NH3 emission from slurry application.

```
my $nh3_loss = scale(
  # only pigs
  scale(
    multiplyPairwise(
      Val(has_pigs, ::Livestock),
      Val(tan_into_application_liquid, ::Storage)
    ),
    (1 - Val(share_fermented_slurry, Slurry::Cfermented)) *
    Tech(er_App_pigs_liquid)
  ) P+
  # only cattle
  scale(
    multiplyPairwise(
      Val(has_cattle, ::Livestock),
      Val(tan_into_application_liquid, ::Storage)
    ),
    (1 - Val(share_fermented_slurry, Slurry::Cfermented)) *
    Tech(er_App_cattle_liquid)
  ) P+
  # both
  scale(
    Val(tan_into_application_liquid, ::Storage),
    Val(share_fermented_slurry, Slurry::Cfermented) *
```

```
    Tech(er_App_fermented_slurry) +
    Val(c_app, Slurry::Applrate)
  ),
  # other factors affecting emission
  Val(c_tech, Slurry::Ctech) *
  Val(c_soft, Slurry::Csoft) *
  Val(c_season, Slurry::Cseason)
);
```

```
scale($nh3_loss,
  Val(c_free_factor_application, Slurry::CfreeFactor));
```

ef_nh3_application_liquid_correct NH3 Emission factor slurry application.

```
Out(nh3_napplication_liquid) P/
  (
    Val(tan_into_application_liquid, ::Storage) P+
    add(
      sign(Val(tan_into_application_liquid, ::Storage)),
      -1
  )
);
```

er_n2_napplication_liquid Total annual N2 emission from slurry application.

```
scale(
  Val(has_no_poultry, ::Livestock),
  Tech(er_n2_App_liquid)
);
```

er_no_napplication_liquid Total annual NO emission from slurry application.

```
scale(
  Val(has_no_poultry, ::Livestock),
  Tech(er_no_App_liquid)
);
```

er_n2o_napplication_liquid Total annual N2O emission from slurry application.

```
scale(
  Val(has_no_poultry, ::Livestock),
  Tech(er_n2o_App_liquid)
);
```

Technical Parameters

er_App_cattle_liquid 0.5

Emission rate for slurry application based on TAN of the slurry. The average rate has been derived from Sommer (2001b), Sogaard et al. (2002), Menzi et al. (1998), Menzi et al. (1997a)

er_App_pigs_liquid 0.35

Die Emissionsrate wurde gemäss ALFAM Modell (Sogaard et al., 2002) berechnet mit folgenden Inputdaten: durchschnittliche Temperatur von März bis November: 12°C (Daten SMA Station Bern Liebefeld 1993-2002); Windgeschwindigkeit von 1 m/s: Schweinegülle Mast: TAN Gehalt Gülle: 2.1 kg/m3 (Verdünnung 1:1, d.h. 2.5 % TS gemäss Flisch et al., 2009); ohne Korrekturen für emissionsminderende Ausbringung, ohne Einarbeitung nach Ausbringung; Ausbringungsmenge: 30 m3/ha; mikrometeorologische Messung: 30.3 % TAN (Mittelwert Boden feucht, Boden trocken). Bei gleichen Annahmen, jedoch einer reduzierten Ausbringungsmenge von 20 m3/ha (aufgrund des im Vergleich zu Rindergülle höheren TAN-Gehalts) und eines TS Gehalts von 3 % (höherer Strohanteil bei Labelsystemen): 33.2 %. Unter den analogen Annahmen resultieren für Schweinegülle Zucht (TAN

Gehalt Gülle: 1.65 kg/m3; Verdünnung 1:1, d.h. 2.5 % TS gemäss Flisch et al., 2009) Emissionsraten von 32.9 % bzw. 36.2 % TAN.

er_App_fermented_slurry 0.53
Emission rate for fermented slurry based on TAN of the slurry.

er_n2_App_liquid 0.0
Emission rate for manure application. Not considerd relevant

er_no_App_liquid 0.0055
Emission rate for manure application. Stehfest, Bouwman 2006

er_n2o_App_liquid 0.01
Emission rate for manure application. ICCP 2006: v4_11Ch_11; Tab11.1

4.3 Application::Slurry::Ctech

This process computes the correction factor according to the technology used for the slurry application.

4.3.1 References:

UNECE 2007. Guidance document on control techniques for preventing and abating emissions of ammonia. UNECE executive body for the convention on long-range transboundary air pollution, Working Group on Strategies and Review, EB.AIR/WH.5/2007/13/ 16 July 2007, Genf. 35p.

Frick R, Menzi H 1997. Hofdüngeranwendung: Wie Ammoniakverluste vermindern? Auch einfache Massnahmen wirken. FAT Bericht 496.

Menzi H, Frick R, Kaufmann R 1997. Ammoniak-Emissionen in der Schweiz: Ausmass und technische Beurteilung des Reduktionspotentials. Eidgenössische Forschungsanstalt für Agrarökologie und Landbau, Zürich-Reckenholz. 107pp.

Inputs

share_splash_plate Share of slurry applied with splash plate.

share_trailing_hose Share of slurry applied with trailing hose.

share_trailing_shoe Share of slurry applied with trailing shoes.

share_shallow_injection Share of slurry applied with shallow injection.

share_deep_injection Share of slurry applied with deep injection.

Outputs

share_deep_injection Share

```
In(share_deep_injection) / 100;
```

share_shallow_injection Share

```
In(share_shallow_injection) / 100;
```

share_trailing_shoe Share

```
In(share_trailing_shoe) / 100;
```

share_trailing_hose Share

```
In(share_trailing_hose) / 100;
```

share_splash_plate Share

```
In(share_splash_plate) / 100;
```

c_tech Reduction factor for the emission due to the used application technology as compared to broadcasting.

```
if( abs( Out(share_deep_injection) +
      Out(share_shallow_injection) +
      Out(share_trailing_shoe) +
      Out(share_trailing_hose) +
      Out(share_splash_plate)
      - 1)  < 1e-8 )
{

    return 1 + ( Out(share_deep_injection) * Tech(red_deep_injection) +
          Out(share_shallow_injection) * Tech(red_shallow_injection) +
          Out(share_trailing_shoe) * Tech(red_trailing_shoe) +
          Out(share_trailing_hose) * Tech(red_trailing_hose) +
```

```
            Out(share_splash_plate) * Tech(red_splash_plate)
        );
    }
    else{
        writeLog({en => "Please correct accordingly: the categories of slurry application do not add up to 100\%!
                  de => "Bitte korrigieren: die Summe der Kategorien Gülleausbringung ist nicht gleich 100\%!\n",
                  fr => "Veuillez corriger : la somme des catégories «Epandage du lisier» n'est pas égale à 100%
      # Warning + Test!
              return 1 + ( Out(share_deep_injection) * Tech(red_deep_injection) +
                Out(share_shallow_injection) * Tech(red_shallow_injection) +
                Out(share_trailing_shoe) * Tech(red_trailing_shoe) +
                Out(share_trailing_hose) * Tech(red_trailing_hose) +
                    Out(share_splash_plate) * Tech(red_splash_plate)
                );
    }
```

Technical Parameters

red_splash_plate 0.0
: There is no reduction for broadcasting with splash plate as to this way of applying slurry all the other methods are compared to.

red_trailing_hose -0.3
: Reduction efficiency as compared to broadcasting applying trailing hose. Adopted from UNECE (2007), Frick and Menzi (1997) and Menzi et al. (1997).

red_trailing_shoe -0.5
: Reduction efficiency as compared to broadcasting applying trailing shoe. Adopted from UNECE (2007), Frick and Menzi (1997) and Menzi et al. (1997).

red_shallow_injection -0.7
: Reduction efficiency as compared to broadcasting applying shallow injection. Adopted from UNECE (2007), Frick and Menzi (1997) and Menzi et al. (1997).

red_deep_injection -0.8
: Reduction efficiency as compared to broadcasting applying deep injection. Adopted from UNECE(2007), Frick and Menzi (1997) and Menzi et al. (1997).

4.4 Application::Slurry::Applrate

This process computes the correction factor as a function of the application rate and the TAN content of the slurry. The equation has been described by Menzi et al. (1998). The correction factor is calculated based on the slurry application rate per ha and the TAN content of the slurry compared to the emission rate occurring with a standard application rate of 30 m3 and a TAN content of 1.15 kg N / m3.

4.4.1 References:

Menzi H, Katz, P E, Fahrni M, Neftel A, Frick R 1998. A simple empirical model based on regression analysis to estimate ammonia emissions after manure application. Atmospheric Environment 32: 301-307.

TODO (Haral Menzi): Please confirm, as description was not finished by Beat Reidy, appl_rate and tan was not included in calculation.

Inputs

dilution_parts_water Specific slurry dilution. TAN contents have been calculated based on a standard dilution of 1:1 with a TAN content of 1.15 kg N /m3.

appl_rate Application rate, mean volume of slurry applied on a ha per deployment.

Outputs

TAN_content TAN content of the slurry compared to the emission rate occuring with a standard application rate of 30 m3 and a TAN content of 1.15 kg N / m3.

```
2.3*(1/(In(dilution_parts_water)+1));
```

c_app Correction factor taking into account the slurry application rate per ha and the TAN content of the slurry.

```
if ( (In(appl_rate) * Out(TAN_content)) > 0 ) {
   (19.41 * Out(TAN_content) + 4.2 * 1.102 - 9.51) *
   (In(appl_rate) * 0.0214 + 0.36) /
   (In(appl_rate) * Out(TAN_content)) -
   Tech(norm_er);
} else {
  return 1;
}
```

Technical Parameters

norm_er 0.5
Standard emission of 50% of the applied TAN calculated based on an equation published by Menzi et al (1998) using a TAN standard of 1.15 kg / m3 for an 1:1 dilution, with application rate (AR) standard of 30 m3 / ha and average swiss meteorological conditions (T=12 C, humitity=70%): ((19.41 * TAN-standard + 4.2 * 1.102 - 9.51) * (0.0214 * AR-standard + 0.36) / (AR-standard * TAN-standard)))

4.5 Application::Slurry::Csoft

This process computes the correction factor if different soft measures for slurry application are respected.

4.5.1 References:

Menzi H, Frick R, Kaufmann R 1997. Ammoniak-Emissionen in der Schweiz: Ausmass und technische Beurteilung des Reduktionspotentials. Eidgenössische Forschungsanstalt für Agrarökologie und Landbau, Zürich-Reckenholz. 107pp.

Frick R, Menzi H 1997. Hofdüngeranwendung: Wie Ammoniakverluste vermindern? Auch einfache Massnahmen wirken. FAT Bericht Nr. 496.

Inputs

appl_evening Share of slurry applied in the evening after 18:00.

appl_hotdays Proportion of slurry applied on hot days.

Outputs

c_soft Correction factor of the emission rate if slurry is applied by considering different kinds of "soft measures".

```
1 +
In(appl_evening) / 100 * Tech(c_evening) +
$TE->{'c_hotdays_'.In(appl_hotdays)};
```

Technical Parameters

c_evening -0.2
Correction factor of the emission rate if slurry is applied in the evening (after 18h)(Menzi et al 1997; Frick and Menzi 1997).

Assumption based on a single experiment with an application after 18h in August at a temperature of >20Â°C: reduction of the emission by 38%, the reduction of the emission averaged over the whole year is only 50%, i.e. -0.2 The correction is omitted for solid manure since infiltration into soil does not occur.

c_hotdays_frequently 0.05
Correction factor of the emission rate if slurry is applied frequently on hot days.

Loss calculated according to the model of Katz (Menzi et al. 1997b) at 17Â°C (i.e. +5Â°C) compared to the reference temperature of 12Â°C (other parameters: 70% rela-tive air humidity, 1.15 kg/m3 TAN, 30 m3/ha) resulting in a loss of 19.22 kg N/ha at 17 Â°C and 55.7% TAN, respectively (compared to 17.45 kg N/ha and 50.6% TAN at 12Â°C, respectively) which corresponds to an increase of 10.1% (rounded to 10%).

c_hotdays_sometimes 0.0
Correction factor of the emission rate if slurry is applied sometimes on hot days (estimation based on Menzi et al (1997)).

c_hotdays_rarely -0.02
Correction factor of the emission rate if slurry is applied rarely on hot days (estimation based on Menzi et al (1997)).

c_hotdays_never -0.04
Correction factor of the emission rate if slurry is applied never on hot days (estimation based on Menzi et al (1997)).

4.6 Application::Slurry::Cseason

This process computes the correction factor for the seasons the slurry is applied.

4.6.1 References:

Menzi H, Frick R, Kaufmann R 1997. Ammoniak-Emissionen in der Schweiz: Ausmass und technische Beurteilung des Reduktionspotentials. Eidgenössische Forschungsanstalt für Agrarökologie und Landbau, Zürich-Reckenholz. 107pp.

Frick R, Menzi H 1997. Hofdüngeranwendung: Wie Ammoniakverluste vermindern? Auch einfache Massnahmen wirken. FAT Bericht Nr. 496.

Inputs

appl_summer Share of slurry applied June to August (in %).

appl_autumn_winter_spring Share of slurry applied September to May.

Outputs

appl_summer .

```
In(appl_summer) / 100;
```

appl_autumn_winter_spring .

```
In(appl_autumn_winter_spring) / 100;
```

c_season Correction factor of the standard emission rate depending on season of application.

```
if( abs(Out(appl_summer)+Out(appl_autumn_winter_spring)-1) < 0.000001 ){
    return (1 + ( Out(appl_summer) * Tech(c_summer) +
                Out(appl_autumn_winter_spring) * Tech(c_autumn_winter_spring)));
}
else {
    writeLog({en => "Please correct accordingly: the categories of \"share of slurry application from June to
                   . "and \"share of slurry application from September to May\" do not add up to 100\%!",
              de => "Bitte korrigieren: die Summe der Kategorien Ausbringung von Gülle im Sommer und von "
                   . "September bis Mai ist nicht gleich 100\%\n",
              fr => "Veuillez corriger: la somme des catégories «Part de lisier épandu en été» et «de "
                   . "septembre à mai» n'est pas égale à 100% !\n"
              });
    # Warning!
    return (1 + ( Out(appl_summer) * Tech(c_summer) +
             Out(appl_autumn_winter_spring) * Tech(c_autumn_winter_spring)));
}
```

Technical Parameters

c_summer 0.15
Correction factor for the application of slurry in summer (June to August): Model calculation according to the model of Katz (Menzi et al. 1997b) with meteorological data from Liebefeld 1993-2002: average from March to November 12°C, 70% relative air humidity, 1.15 kg/m3 TAN, 30 m3/ha resulting in a loss of 50.6% TAN; summer 17.8°C resulting in a loss of 56.7% TAN (+12%). Value chosen for cal-culation: +15%

c_autumn_winter_spring -0.05
Correction factor for the application of slurry in autumn, winter and spring (Sept to May): Model calculation according to the model of Katz (Menzi et al. 1997b) with meteorological data from Liebefeld 1993-2002: average from March to November 12°C, 70% relative air

humidity, 1.15 kg/m3 TAN, 30 m3/ha resulting in a loss of 50.6% TAN; spring/autumn/winter 9°C resulting in a loss of 48.1% TAN (-4.8%). Value chosen for calculation: -5%

4.7 Application::Slurry::Cfermented

This process computes the correction factor of fermented slurry

4.7.1 References:

Inputs

fermented_slurry Share of anaerobically digested slurry

Outputs

share_fermented_slurry Share of fermented slurry.

```
In(fermented_slurry)/100;
```

4.8 Application::Slurry::CfreeFactor

Inputs

free_correction_factor Factor to define free ?

Outputs

c_free_factor_application Free reduction of the Emission rate for the Yard.

```
if(In(free_correction_factor)//0 != 0) {
    writeLog({en=>"You have entered an additional emission mitigation measure for a application of slurry of
                  . In(free_correction_factor)
                  . "\% !\n",
              de=>"Sie haben eine zusätzliche emissionsmindernde Massnahme für die Ausbringung von Gülle von
                  . In(free_correction_factor)
                  . "\% eingegeben!\n",
              fr=>"Vous avez introduit une mesure supplémentaire limitant les émissions dues à l'épandage de
                  . "\% !\n"});
          return 1 - In(free_correction_factor)/100;
 } else {
   return 1;
 }
```

4.9 Application::SolidManure::Solid

This process computes the annual average NH3 emission from solid manure application (liquid/solid and deep litter). The standard emission factor is corrected according to the TAN content and the application rate, the application technology, the crops to which the manure is applied, respected soft measures during application and the application season, the time lag between application and incorporation, the incorporation technology used, and the proportion of solid manure that is applied on hot days.

4.9.1 References:

Menzi H, Keller M, Katz P, Fahrni M, Neftel A 1997. Ammoniakverluste nach der Anwendung von Mist. Agrarforschung 4:328-331.

Menzi H, Katz P, Frick R, Fahrni M, Keller M 1997: Ammonia emissions following the application of solid manure to grassland. In: Jarvis S.C. and Pain B.F. (Eds.): "Nitrogen Emissions from Grassland", CAB, 265-274.

Webb, J., Sommer, S.G., Kupper, T., Groenestein, C.M., Hutchings, N., Eurich-Menden, B., Rodhe, L., Misselbrook, T., Amon, B. 2012. Emissions of ammonia, nitrous oxide and methane during the management of solid manures. A review. In: Lichtfouse, E., (eds.). Agroecology and Strategies for Climate Change. Heidelberg, Germany: Springer-Verlag GmbH. pp 67-108.

Outputs

er_nh3_napplication_solid_no_poultry NH3 emission rates for solid manure application from all animal categories except poultry.

```
scale(
  # er cattle
  scale(
    Val(has_cattle, ::Livestock),
    Tech(er_App_manure_dairycows_cattle)
  ) P+
  # er pigs
  scale(
    Val(has_pigs, ::Livestock),
    Tech(er_App_manure_pigs)
  ) P+
  # er others
  scale(
    Val(has_others, ::Livestock),
    Tech(er_App_manure_horses_otherequides_smallruminants)
  ),
  # other factors
  Val(c_incorp_time, Solid::CincorpTime) *
  Val(c_season, Cseason) *
  Val(c_free_factor_application_solidmanure, CfreeFactor)
);
```

er_n2_napplication_solid_no_poultry N2 emission rates for solid manure application from all animal categories except poultry.

```
scale(
  Val(has_no_poultry, ::Livestock),
  Tech(er_n2_App_manure)
);
```

er_no_napplication_solid_no_poultry N2 emission rates for solid manure application from all animal categories except poultry.

```
scale(
  Val(has_no_poultry, ::Livestock),
```

```
    Tech(er_no_App_manure)
  );
```

er_n2o_napplication_solid_no_poultry N2 emission rates for solid manure application from all animal categories except poultry.

```
scale(
  Val(has_no_poultry, ::Livestock),
  Tech(er_n2o_App_manure)
);
```

Technical Parameters

er_App_manure_dairycows_cattle 0.8
Emission rate for manure application. The average rate has been derived from Frick et al. (1996) and Menzi et al. (1996). The value is based on the average emissions from diffrent Swiss experiments. Emission based on TAN content of solid manure.

er_App_manure_pigs 0.6
Emission rate for manure application. Based on EAGER Review on Solid Manure, Webb et al. (2012), Emission based on TAN of slurry.

er_App_manure_horses_otherequides_smallruminants 0.7
Emission rate for manure application. The average rate has been derived from Frick et al. (1996) and Menzi et al. (1996). The value is based on the average emissions from diffrent Swiss experiments. Emission based on TAN of slurry.

er_n2_App_manure 0.0
Emission rate for manure application. Not considerd relevant

er_no_App_manure 0.0055
Emission rate for manure application. Stehfest, Bouwman 2006

er_n2o_App_manure 0.01
Emission rate for manure application. ICCP 2006: v4_11Ch_11; Tab11.1

4.10 Application::SolidManure::Solid::CincorpTime

This process computes the correction factor for the time lag between application and incorporation of the solid manure.

4.10.1 References:

Menzi H, Keller M, Katz P, Fahrni M, Neftel A 1997. Ammoniakverluste nach der Anwendung von Mist. Agrarforschung 4:328-331.

Outputs

c_incorp_time Correction factor taking into account the time lag between application and incorporation of the solid manure.

```
return 1 + ( Val(incorp_lw1h,..::CincorpTime) * Tech(eff_inc_lw1h) +
      Val(incorp_lw4h,..::CincorpTime) * Tech(eff_inc_lw4h) +
      Val(incorp_lw8h,..::CincorpTime) * Tech(eff_inc_lw8h) +
      Val(incorp_lw1d,..::CincorpTime) * Tech(eff_inc_lw1d) +
      Val(incorp_lw3d,..::CincorpTime) * Tech(eff_inc_lw3d) +
      Val(incorp_gt3d,..::CincorpTime) * Tech(eff_inc_gt3d) +
      Val(incorp_none,..::CincorpTime) * Tech(eff_inc_none)
     );
```

Technical Parameters

eff_inc_lw1h -0.9
Reduction due to incorporation of solid manure within 1 hour. UNECE (2007).

eff_inc_lw4h -0.7
Reduction due to incorporation of solid manure within 4 hours. Empirical estimate deduced from UNECE (2007). Mean value between the category incorporation within 1 hour and incorporation within 8 hours.

eff_inc_lw8h -0.5
Reduction due to incorporation of solid manure within 8 hours. Values adapted from UNECE (2007) (category Incorporation by plough within 12 h)

eff_inc_lw1d -0.35
Reduction due to incorporation of solid manure within 1 day. Values adapted from UNECE (2007) Empirical estimate deduced from Menzi et al. (1997).

eff_inc_lw3d -0.3
Reduction due to incorporation of solid manure within 3 days. Empirical estimate deduced from Menzi et al. (1997).

eff_inc_gt3d -0.1
Reduction due to incorporation of solid manure after 3 days Empirical estimate deduced from Menzi et al. (1997).

eff_inc_none 0.0
Basis with no incorporation of solid manure.

4.11 Application::SolidManure::CincorpTime

This process computes the correction factor for the time lag between application and incorporation of the solid manure (from all animal categories).

4.11.1 References:

Menzi H, Keller M, Katz P, Fahrni M, Neftel A 1997. Ammoniakverluste nach der Anwendung von Mist. Agrarforschung 4:328-331.

Inputs

incorp_lw1h Share of incorporated solid manure within 1 hour.

incorp_lw4h Share of incorporated solid manure within 4 hours.

incorp_lw8h Share of incorporated solid manure within 8 hours.

incorp_lw1d Share of incorporated solid manure within 1 day.

incorp_lw3d Share of incorporated solid manure within 3 days.

incorp_gt3d Share of incorporated solid manure after 3 days.

incorp_none Share of solid manure not incorporated.

Outputs

incorp_lw1h Share of incorporated solid manure within 1 hour.

```
In(incorp_lw1h) / 100;
```

incorp_lw4h Share of incorporated solid manure within 4 hour.

```
In(incorp_lw4h) / 100;
```

incorp_lw8h Share of incorporated solid manure within 8 hour.

```
In(incorp_lw8h) / 100;
```

incorp_lw1d Share of incorporated solid manure within 1 day.

```
In(incorp_lw1d) / 100;
```

incorp_lw3d Share of incorporated solid manure within 3 days.

```
In(incorp_lw3d) / 100;
```

incorp_gt3d Share of incorporated solid manure after 3 days.

```
In(incorp_gt3d) / 100;
```

incorp_none Share of not-incorporated solid manure.

```
In(incorp_none) / 100;
```

test_incorp_time Correction factor taking into account the time lag between application and incorporation of the solid manure.

```
if( ( Out(incorp_lw1h) +
      Out(incorp_lw4h) +
      Out(incorp_lw8h) +
      Out(incorp_lw1d) +
      Out(incorp_lw3d) +
      Out(incorp_gt3d) +
      Out(incorp_none)
     ) >= 0.999999
     && ( Out(incorp_lw1h) +
      Out(incorp_lw4h) +
```

```
      Out(incorp_lw8h) +
      Out(incorp_lw1d) +
      Out(incorp_lw3d) +
      Out(incorp_gt3d) +
      Out(incorp_none)
     ) <= 1.000001
   ){  return 1;
}else{
      writeLog({en=>"Please correct accordingly: the categories of solid manure incorporated do not add up to
            de=>"Bitte korrigieren: die Summe der Kategorien Einarbeitung von Mist ist nicht gleich 100\%!",
            fr=>"Veuillez corriger : la somme des catégories «Part de fumier incorporé» n'est pas égale à 100
           } );
      return  0;
}
```

4.12 Application::SolidManure::Cseason

This process computes the correction factor for the seasons the solid manure is applied.

4.12.1 References:

Menzi H, Frick R, Kaufmann R 1997. Ammoniak-Emissionen in der Schweiz: Ausmass und technische Beurteilung des Reduktionspotentials. Eidgenössische Forschungsanstalt für Agrarökologie und Landbau, Zürich-Reckenholz. 107pp.

Frick R, Menzi H 1997. Hofdüngeranwendung: Wie Ammoniakverluste vermindern? Auch einfache Massnahmen wirken. FAT Bericht Nr. 496.

Inputs

appl_summer Share of solid manure applied June to August (in %).

appl_autumn_winter_spring Share of solid manure applied September to May (in %).

Outputs

appl_summer .

```
In(appl_summer) / 100;
```

appl_autumn_winter_spring .

```
In(appl_autumn_winter_spring) / 100;
```

c_season Correction factor of the standard emission rate depending on season of application.

```
if( abs(Out(appl_summer)+Out(appl_autumn_winter_spring) - 1) < 0.000001 ){
    (1 + ( Out(appl_summer) * Tech(c_summer) +
    Out(appl_autumn_winter_spring) * Tech(c_autumn_winter_spring)));
}
else {
    writeLog({en => "Please correct accordingly: the categories of seasonal solid manure incorporated do not
              de => "Bitte korrigieren: die Summe der Kategorien der saisonalen Einarbeitung von Mist ist nic
              fr => "Veuillez corriger : la somme des catégories «Part de fumier incorporé» n'est pas égale à
             });
    (1 + ( Out(appl_summer) * Tech(c_summer) +
           Out(appl_autumn_winter_spring) * Tech(c_autumn_winter_spring)));
}
```

Technical Parameters

c_summer 0.15
Correction factor for the application of solid manure in summer (June to August): Model calculation according to the model of Katz (Menzi et al. 1997b) with meteorological data from Liebefeld 1993-2002: average from March to November 12°C, 70% relative air humidity, 1.15 kg/m3 TAN, 30 m3/ha resulting in a loss of 50.6% TAN; summer 17.8°C resulting in a loss of 56.7% TAN (+12%). Value chosen for cal-culation: +15%.

c_autumn_winter_spring -0.05
Correction factor for the application of solid manure in autumn, winter and spring (Sept to May): Model calculation according to the model of Katz (Menzi et al. 1997b) with meteorological data from Liebefeld 1993-2002: average from March to November 12°C, 70% relative air humidity, 1.15 kg/m3 TAN, 30 m3/ha resulting in a loss of 50.6% TAN; spring/autumn/winter 9°C resulting in a loss of 48.1% TAN (-4.8%). Value chosen for calculation: -5%.

4.13 Application::SolidManure::CfreeFactor

Inputs

free_correction_factor Factor to define free ?

Outputs

c_free_factor_application_solidmanure Free reduction of the Emission rate for the Yard.

```
if(In(free_correction_factor)//0 != 0) {
    writeLog({en=>"You have entered an additional emission mitigation measure for a application of solid manu
                  . In(free_correction_factor)
                  . "\%!\n",
              de=>"Sie haben eine zusätzliche emissionsmindernde Massnahme für die Ausbringung von Mist von "
                    . In(free_correction_factor)
                  . "\% eingegeben!\n",
              fr=>"Vous avez introduit une mesure supplémentaire limitant les émissions dues à l'épandage de
                  . In(free_correction_factor) . "\% !\n"});
          return 1 - In(free_correction_factor)/100;

} else {
  return 1;
}
```

4.14 Application::SolidManure::Poultry

This process computes the annual average NH3 emission from poultry manure application. The standard emission factor is corrected according to the TAN content and the application rate, the application technology, the crops to which the manure is applied, respected soft measures during application and the application season, the time lag between application and incorporation, the incorporation technology used, and the proportion of solid manure that is applied on hot days.

The correction factor are based on the same input parameters as the application for solid manure.

4.14.1 References:

Menzi H, Keller M, Katz P, Fahrni M, Neftel A 1997. Ammoniakverluste nach der Anwendung von Mist. Agrarforschung 4:328-331.

Menzi H, Katz P, Frick R, Fahrni M, Keller M 1997: Ammonia emissions following the application of solid manure to grassland. In: Jarvis S.C. and Pain B.F. (Eds.): "Nitrogen Emissions from Grassland", CAB, 265-274.

TODO (Cyrill Bonjour): Add correct calculation based on Ntot and TAN!

Outputs

er_nh3_napplication_solid_poultry NH3 emission rate for solid manure application.

```
scale(
  Val(has_poultry, ::Livestock),
  Tech(er_App_manure) *
  Val(c_incorp_time, Poultry::CincorpTime) *
  Val(c_season, Cseason) *
  Val(c_free_factor_application_solidmanure, CfreeFactor)
);
```

er_n2_napplication_solid_poultry N2 emission from solid manure application from poultry.

```
scale(
  Val(has_poultry, ::Livestock),
  Tech(er_n2_App_manure)
);
```

er_no_napplication_solid_poultry NO emission from solid manure application from poultry.

```
scale(
  Val(has_poultry, ::Livestock),
  Tech(er_no_App_manure)
);
```

er_n2o_napplication_solid_poultry N2O emission from solid manure application from poultry.

```
scale(
  Val(has_poultry, ::Livestock),
  Tech(er_n2o_App_manure)
);
```

Technical Parameters

er_App_manure 0.4
Emission rate for manure application. Not considerd relevant

er_n2_App_manure 0.0
Emission rate for manure application. Based on EAGER Review on Solid Manure, Webb et al. (2012), Emission based on TAN content of solid manure.

er_no_App_manure 0.0055
Emission rate for manure application. Stehfest, Bouwman 2006

er_n2o_App_manure 0.01
Emission rate for manure application. ICCP 2006: v4_11Ch_11; Tab11.1

4.15 Application::SolidManure::Poultry::CincorpTime

This process computes the correction factor for the time lag between application and incorporation of the poultry manure.

4.15.1 References:

Menzi H, Keller M, Katz P, Fahrni M, Neftel A 1997. Ammoniakverluste nach der Anwendung von Mist. Agrarforschung 4:328-331.

Menzi H, Katz P, Frick R, Fahrni M, Keller M 1997: Ammonia emissions following the application of solid manure to grassland. In: Jarvis S.C. and Pain B.F. (Eds.): ”Nitrogen Emissions from Grassland”, CAB, 265-274.

UNECE 2007. Guidance document on control techniques for preventing and abating emissions of ammonia. ECE/EB.AIR/WG.5/2007/13.

Outputs

c_incorp_time Correction factor taking into account the time lag between application and incorporation of the solid manure.

```
return  1 + ( Val(incorp_lw1h,..::CincorpTime) * Tech(eff_inc_lw1h) +
      Val(incorp_lw4h,..::CincorpTime) * Tech(eff_inc_lw4h) +
      Val(incorp_lw8h,..::CincorpTime) * Tech(eff_inc_lw8h) +
      Val(incorp_lw1d,..::CincorpTime) * Tech(eff_inc_lw1d) +
      Val(incorp_lw3d,..::CincorpTime) * Tech(eff_inc_lw3d) +
      Val(incorp_gt3d,..::CincorpTime) * Tech(eff_inc_gt3d) +
      Val(incorp_none,..::CincorpTime) * Tech(eff_inc_none)
     );
```

Technical Parameters

eff_inc_lw1h -0.95
Reduction due to incorporation of solid manure within 1 hour. UNECE (2007).

eff_inc_lw4h -0.8
Reduction due to incorporation of solid manure within 4 hours. Empirical estimate deduced from UNECE (2007). Mean value between the category incorporation within 1 hour and incorporation within 8 hours.

eff_inc_lw8h -0.7
Reduction due to incorporation of solid manure within 8 hours. Values adapted from UNECE (2007) (category Incorporation by plough within 12 h)

eff_inc_lw1d -0.55
Reduction due to incorporation of solid manure within 1 day. Values adapted from UNECE (2007) Empirical estimate deduced from Menzi et al. (1997).

eff_inc_lw3d -0.3
Reduction due to incorporation of solid manure within 3 days. Empirical estimate deduced from Menzi et al. (1997).

eff_inc_gt3d -0.1
Reduction due to incorporation of solid manure after 3 days Empirical estimate deduced from Menzi et al. (1997).

eff_inc_none 0.0
Basis with no incorporation of solid manure.

5 Stage PlantProduction

5.1 PlantProduction

This process summarizes the contribution of the plant production to the total NH3 emission.

5.1.1 Differences to DYNAMO

Outputs

nh3_nplantproduction Annual NH3 emission from plant production.

```
Val(nh3_nmineralfertiliser, PlantProduction::MineralFertiliser) +
Val(nh3_nrecyclingfertiliser, PlantProduction::RecyclingFertiliser)
```

compost Amount of compost in t per year.

```
Val(compost, PlantProduction::RecyclingFertiliser);
```

solid_digestate Amount of Solid digestate in t per year.

```
Val(solid_digestate, PlantProduction::RecyclingFertiliser);
```

liquid_digestate Amount of liquid digestate in m3 per year.

```
Val(liquid_digestate, PlantProduction::RecyclingFertiliser);
```

5.2 PlantProduction::MineralFertiliser

This process computes the annual average NH3 emission from mineral fertiliser application.

5.2.1 References:

Qiao, C.L., Liu, L.L., Hu, S.J., Compton, J.E., Greaver, T.L., Li, Q.L. 2015. How inhibiting nitrification affects nitrogen cycle and reduces environmental impacts of anthropogenic nitrogen input. Global Change Biol. 21(3): 1249-1257.

Pan, B.B., Lam, S.K., Mosier, A., Luo, Y.Q., Chen, D.L. 2016. Ammonia volatilization from synthetic fertilizers and its mitigation strategies: A global synthesis. Agric. Ecosyst. Environ. 232: 283-289.

Inputs

soil_ph Soil pH value

mineral_fertiliser_ammoniumNitrate_amount Amount of ammonium nitrate in kg fertilizer/year.

mineral_fertiliser_ammoniumNitrate_N_content N content of ammonium nitrate in percent

mineral_fertiliser_calciumAmmoniumNitrate_amount Amount of calcium ammonium nitrate in kg fertilizer/year.

mineral_fertiliser_calciumAmmoniumNitrate_N_content N content of calcium ammonium nitrate in percent

mineral_fertiliser_ammoniumSulphate_amount Amount of ammonium sulphate in kg fertilizer/year.

mineral_fertiliser_ammoniumSulphate_N_content N content of ammomiun sulphate in percent

mineral_fertiliser_urea_amount Amount of urea in kg fertilizer/year.

mineral_fertiliser_urea_N_content N content of urea in percent

mineral_fertiliser_sulfamid_amount Amount of sulfamid in kg fertilizer/year.

mineral_fertiliser_sulfamid_N_content N content of sulfamid in percent

mineral_fertiliser_calciumNitrate_amount Amount of calcium nitrate (Kalksalpeter) in kg fertilizer/year.

mineral_fertiliser_calciumNitrate_N_content N content of calcium nitrate (Kalksalpeter) in percent

mineral_fertiliser_calciumCyanamid_amount Amount of calcium cyanamid in kg fertilizer/year.

mineral_fertiliser_calciumCyanamid_N_content N content of calcium cyanamid in percent

mineral_fertiliser_entec_amount Amount of entec in kg fertilizer/year.

mineral_fertiliser_entec_N_content N content of Entec in percent

mineral_fertiliser_np_amount Amount of NP mixtures in kg fertilizer/year.

mineral_fertiliser_np_N_content N content of NP mixtures in percent

mineral_fertiliser_nk_amount Amount of NK mixtures in kg fertilizer/year.

mineral_fertiliser_nk_N_content N content of NK mixtures in percent

mineral_fertiliser_npk_amount Amount of NPK mixtures in kg fertilizer/year.

mineral_fertiliser_npk_N_content N content of NPK mixtures in percent

mineral_fertiliser_entec2_amount Amount of Entec2 in kg fertilizer/year.

mineral_fertiliser_entec2_N_content N content of Entec2 in percent

mineral_fertiliser_other_amount Amount of other mineral fertilizers in kg fertilizer/year.

mineral_fertiliser_other_N_content N content of other mineral fertilizers in percent

Outputs

nh3_n_mineral_fertiliser_ammoniumNitrate NH3 emission from mineral fertiliser application from ammonium nitrate.

```
my $nAmount = In(mineral_fertiliser_ammoniumNitrate_amount) * In(mineral_fertiliser_ammoniumNitrate_N_content
my $ph = In(soil_ph);
my $er = $TE->{'er_mineral_fertiliser_ammoniumNitrate_' . $ph . '_pH'};
return $nAmount * $er;
```

nh3_n_mineral_fertiliser_calciumAmmoniumNitrate NH3 emission from mineral fertiliser application from calcium ammonium nitrate.

```
my $nAmount = In(mineral_fertiliser_calciumAmmoniumNitrate_amount) * In(mineral_fertiliser_calciumAmmoniumNit
my $ph = In(soil_ph);
my $er = $TE->{'er_mineral_fertiliser_calciumAmmoniumNitrate_' . $ph . '_pH'};
return $nAmount * $er;
```

nh3_n_mineral_fertiliser_ammoniumSulphate NH3 emission from mineral fertiliser application from ammonium sulphate.

```
my $nAmount = In(mineral_fertiliser_ammoniumSulphate_amount) * In(mineral_fertiliser_ammoniumSulphate_N_conte
my $ph = In(soil_ph);
my $er = $TE->{'er_mineral_fertiliser_ammoniumSulphate_' . $ph . '_pH'};
return $nAmount * $er;
```

nh3_n_mineral_fertiliser_urea NH3 emission from mineral fertiliser application from urea.

```
my $nAmount = In(mineral_fertiliser_urea_amount) * In(mineral_fertiliser_urea_N_content)/100;
my $ph = In(soil_ph);
my $er = $TE->{'er_mineral_fertiliser_urea_' . $ph . '_pH'};
return $nAmount * $er;
```

nh3_n_mineral_fertiliser_sulfamid NH3 emission from mineral fertiliser application from sulfamid

```
my $nAmount = In(mineral_fertiliser_sulfamid_amount) * In(mineral_fertiliser_sulfamid_N_content)/100;
my $ph = In(soil_ph);
my $er = $TE->{'er_mineral_fertiliser_sulfamid_' . $ph . '_pH'};
return $nAmount * $er;
```

nh3_n_mineral_fertiliser_calciumNitrate NH3 emission from mineral fertiliser application from calcium nitrate (Kalksalpeter)

```
my $nAmount = In(mineral_fertiliser_calciumNitrate_amount) * In(mineral_fertiliser_calciumNitrate_N_content)/
my $ph = In(soil_ph);
my $er = $TE->{'er_mineral_fertiliser_calciumNitrate_' . $ph . '_pH'};
return $nAmount * $er;
```

nh3_n_mineral_fertiliser_calciumCyanamid NH3 emission from mineral fertiliser application from calcium cyanamid

```
my $nAmount = In(mineral_fertiliser_calciumCyanamid_amount) * In(mineral_fertiliser_calciumCyanamid_N_content
my $ph = In(soil_ph);
my $er = $TE->{'er_mineral_fertiliser_calciumCyanamid_' . $ph . '_pH'};
return $nAmount * $er;
```

nh3_n_mineral_fertiliser_entec NH3 emission from mineral fertiliser application from Entec

```
my $nAmount = In(mineral_fertiliser_entec_amount) * In(mineral_fertiliser_entec_N_content)/100;
my $ph = In(soil_ph);
```

```
my $er = $TE->{'er_mineral_fertiliser_entec_' . $ph . '_pH'};
return $nAmount * $er;
```

nh3_n_mineral_fertiliser_np NH3 emission from mineral fertiliser application from NP mixtures

```
my $nAmount = In(mineral_fertiliser_np_amount) * In(mineral_fertiliser_np_N_content)/100;
my $ph = In(soil_ph);
my $er = $TE->{'er_mineral_fertiliser_np_' . $ph . '_pH'};
return $nAmount * $er;
```

nh3_n_mineral_fertiliser_nk NH3 emission from mineral fertiliser application from NK mixtures

```
my $nAmount = In(mineral_fertiliser_nk_amount) * In(mineral_fertiliser_nk_N_content)/100;
my $ph = In(soil_ph);
my $er = $TE->{'er_mineral_fertiliser_nk_' . $ph . '_pH'};
return $nAmount * $er;
```

nh3_n_mineral_fertiliser_npk NH3 emission from mineral fertiliser application from NPK mixtures

```
my $nAmount = In(mineral_fertiliser_npk_amount) * In(mineral_fertiliser_npk_N_content)/100;
my $ph = In(soil_ph);
my $er = $TE->{'er_mineral_fertiliser_npk_' . $ph . '_pH'};
return $nAmount * $er;
```

nh3_n_mineral_fertiliser_entec2 NH3 emission from mineral fertiliser application from Entec2

```
my $nAmount = In(mineral_fertiliser_entec2_amount) * In(mineral_fertiliser_entec2_N_content)/100;
my $ph = In(soil_ph);
my $er = $TE->{'er_mineral_fertiliser_entec2_' . $ph . '_pH'};
return $nAmount * $er;
```

nh3_n_mineral_fertiliser_other NH3 emission from mineral fertiliser application from other mineral fertilizers

```
my $nAmount = In(mineral_fertiliser_other_amount) * In(mineral_fertiliser_other_N_content)/100;
my $ph = In(soil_ph);
my $er = $TE->{'er_mineral_fertiliser_other_' . $ph . '_pH'};
return $nAmount * $er;
```

nh3_nmineralfertiliser NH3 emission from mineral fertiliser application.

```
Out(nh3_n_mineral_fertiliser_ammoniumNitrate) +
Out(nh3_n_mineral_fertiliser_calciumAmmoniumNitrate) +
Out(nh3_n_mineral_fertiliser_ammoniumSulphate) +
Out(nh3_n_mineral_fertiliser_urea) +
Out(nh3_n_mineral_fertiliser_sulfamid) +
Out(nh3_n_mineral_fertiliser_calciumNitrate) +
Out(nh3_n_mineral_fertiliser_calciumCyanamid) +
Out(nh3_n_mineral_fertiliser_entec) +
Out(nh3_n_mineral_fertiliser_np) +
Out(nh3_n_mineral_fertiliser_nk) +
Out(nh3_n_mineral_fertiliser_npk) +
Out(nh3_n_mineral_fertiliser_entec2) +
Out(nh3_n_mineral_fertiliser_other);
```

Technical Parameters

er_mineral_fertiliser_ammoniumNitrate_low_pH 0.012
Emission rate for the application of ammonium nitrate, low pH soils.

er_mineral_fertiliser_ammoniumNitrate_high_pH 0.026
Emission rate for the application of ammonium nitrate, high pH soils.

er_mineral_fertiliser_ammoniumNitrate_unknown_pH 0.019
Emission rate for the application of ammonium nitrate, unknown pH soils.

er_mineral_fertiliser_calciumAmmoniumNitrate_low_pH 0.007
Emission rate for the application of calcium ammonium nitrate, low pH soils.

er_mineral_fertiliser_calciumAmmoniumNitrate_high_pH 0.014
Emission rate for the application of calcium ammonium nitrate, high pH soils.

er_mineral_fertiliser_calciumAmmoniumNitrate_unknown_pH 0.01
Emission rate for the application of calcium ammonium nitrate, unknown pH soils.

er_mineral_fertiliser_ammoniumSulphate_low_pH 0.074
Emission rate for the application of ammonium sulphate, low pH soils.

er_mineral_fertiliser_ammoniumSulphate_high_pH 0.136
Emission rate for the application of ammonium sulphate, high pH soils.

er_mineral_fertiliser_ammoniumSulphate_unknown_pH 0.103
Emission rate for the application of ammonium sulphate, unknown pH soils.

er_mineral_fertiliser_urea_low_pH 0.128
Emission rate for the application of urea, low pH soils.

er_mineral_fertiliser_urea_high_pH 0.135
Emission rate for the application of urea, high pH soils.

er_mineral_fertiliser_urea_unknown_pH 0.131
Emission rate for the application of urea, unknown pH soils.

er_mineral_fertiliser_sulfamid_low_pH 0.128
Emission rate for the application of sulfamid, low pH soils.

er_mineral_fertiliser_sulfamid_high_pH 0.135
Emission rate for the application of sulfamid, high pH soils.

er_mineral_fertiliser_sulfamid_unknown_pH 0.131
Emission rate for the application of sulfamid, unknown pH soils.

er_mineral_fertiliser_calciumNitrate_low_pH 0.007
Emission rate for the application of calcium nitrate (Kalksalpeter), low pH soils.

er_mineral_fertiliser_calciumNitrate_high_pH 0.014
Emission rate for the application of calcium nitrate (Kalksalpeter), high pH soils.

er_mineral_fertiliser_calciumNitrate_unknown_pH 0.01
Emission rate for the application of calcium nitrate (Kalksalpeter), unknown pH soils.

er_mineral_fertiliser_calciumCyanamid_low_pH 0.128
Emission rate for the application of calcium cyanamid, low pH soils.

er_mineral_fertiliser_calciumCyanamid_high_pH 0.135
Emission rate for the application of calcium cyanamid, high pH soils.

er_mineral_fertiliser_calciumCyanamid_unknown_pH 0.131
Emission rate for the application of calcium cyanamid, unknown pH soils.

er_mineral_fertiliser_entec_low_pH 0.074
Emission rate for the application of Entec, low pH soils.

er_mineral_fertiliser_entec_high_pH 0.136
Emission rate for the application of Entec, high pH soils.

er_mineral_fertiliser_entec_unknown_pH 0.103
Emission rate for the application of Entec, unknown pH soils.

er_mineral_fertiliser_entec2_low_pH 0.074
Emission rate for the application of Entec as NP, NPK, with/without Mg, S, and trace substances, low pH soils.

er_mineral_fertiliser_entec2_high_pH 0.136
Emission rate for the application of Entec as NP, NPK, with/without Mg, S, and trace substances, high pH soils.

er_mineral_fertiliser_entec2_unknown_pH 0.103
Emission rate for the application of Entec as NP, NPK, with/without Mg, S, and trace substances, unknown pH soils.

er_mineral_fertiliser_np_low_pH 0.041
Emission rate for the application of NP mixtures, low pH soils.

er_mineral_fertiliser_np_high_pH 0.075
Emission rate for the application of NP mixtures, high pH soils.

er_mineral_fertiliser_np_unknown_pH 0.057
Emission rate for the application of NP mixtures, unknown pH soils.

er_mineral_fertiliser_nk_low_pH 0.012
Emission rate for the application of NK mixtures, low pH soils.

er_mineral_fertiliser_nk_high_pH 0.026
Emission rate for the application of NK mixtures, high pH soils.

er_mineral_fertiliser_nk_unknown_pH 0.019
Emission rate for the application of NK mixtures, unknown pH soils.

er_mineral_fertiliser_npk_low_pH 0.041
Emission rate for the application of NPK mixtures, low pH soils.

er_mineral_fertiliser_npk_high_pH 0.075
Emission rate for the application of NPK mixtures, high pH soils.

er_mineral_fertiliser_npk_unknown_pH 0.057
Emission rate for the application of NPK mixtures, unknown pH soils.

er_mineral_fertiliser_other_low_pH 0.012
Emission rate for the application of other fertilizers, low pH soils.

er_mineral_fertiliser_other_high_pH 0.026
Emission rate for the application of other fertilizers, high pH soils.

er_mineral_fertiliser_other_unknown_pH 0.019
Emission rate for the application of other fertilizers, unknown pH soils.

5.3 PlantProduction::RecyclingFertiliser

This process computes the annual average NH3 emission from recycling fertiliser application. The standard emission factor is corrected according to the TAN content and the application rate, the application technology, the crops to which the manure is applied, respected soft measures during application and the application season, the time lag between application and incorporation, the incorporation technology used, and the proportion of solid manure that is applied on hot days.

5.3.1 References:

Vanderweerden and Jarvis (1997)

Inputs

compost Amount of compost (in t fresh matter per year). Kompost besteht aus Grünabfällen nicht-landwirtschaflticher Herkunft von gewerblich-industriellen Anlagen oder von Feldrandkompostierung.

solid_digestate Amount of solid digestate form anaerobic digestion plants

liquid_digestate Amount of liquid digestate form anaerobic digestion plants

Outputs

nh3_ncompost NH3 emission from compost.

```
In(compost) * Tech(er_compost);
```

nh3_nsolid_degestate NH3 emission from solid digestate.

```
In(solid_digestate) * Tech(er_solid_digestate);
```

nh3_nliquid_degestate NH3 emission from liquid digestate.

```
In(liquid_digestate) * Tech(er_liquid_digestate);
```

nh3_nrecyclingfertiliser NH3 emission from total recycling fertiliser.

```
In(liquid_digestate) * Tech(er_liquid_digestate) +
In(solid_digestate) * Tech(er_solid_digestate) +
In(compost) * Tech(er_compost);
```

compost Amount of compost in t /a.

```
In(compost);
```

solid_digestate Amount of Solid digestate in t /a.

```
In(solid_digestate);
```

liquid_digestate Amount of liquid digestate in m3 /a.

```
In(liquid_digestate);
```

Technical Parameters

er_compost 0.24
Emission rate from compost, calculated with an emmission rate of 80
0.3 kg TAN per t fresh matter (Flisch et al., 2009). of TAN.

er_solid_digestate 0.24
Emission rate for solid digestat from industrial plantse, calculated with an emmission rate of 80

er_liquid_digestate 0.84
Emission rate from liquid digestate from industrial plants, calculated with an emmission rate of 60
Assumed